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TRAINING AND TESTING
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Training and Testing Activities
Final Environmental Impact Statement/
Overseas Environmental Impact Statement

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Final
Environmental Impact Statement/Overseas Environmental Impact Statement
Hawaii-Southern California Training and Testing

Lead Agency:	United States Department of the Navy
Cooperating Agency:	National Marine Fisheries Service
Title of the Proposed Action:	Hawaii-Southern California Training and Testing
Designation:	Final Environmental Impact Statement/Overseas Environmental Impact Statement

Abstract

The United States Department of the Navy (Navy) prepared this Environmental Impact Statement (EIS)/Overseas EIS (OEIS) to comply with the National Environmental Policy Act (NEPA) and Executive Order 12114. This EIS/OEIS evaluates the potential environmental impacts of conducting training and testing activities after December 2018 in the Hawaii-Southern California Training and Testing Study Area (Study Area). The Study Area is made up of air and sea space off Southern California, around the Hawaiian Islands, and the transit corridor connecting them. Three alternatives were analyzed in this EIS/OEIS:

- The No Action Alternative would be no training and testing activities associated with the Proposed Action within the Study Area.
- Alternative 1 (Preferred Alternative) reflects a representative year of training and testing to account for the natural fluctuation of training and testing cycles and deployment schedules that generally limit the maximum level of activities from occurring year after year in any 5-year period. Using a representative level of activities rather than maximum level reduces the amount of ship hull-mounted, mid-frequency active sonar estimated to meet requirements. Under Alternative 1, the Navy assumes that some unit-level training and testing would be conducted using synthetic means (e.g., simulators). Additionally, this alternative assumes that some unit-level active sonar training will be completed through other training exercises.
- Under Alternative 2, the Navy would be enabled to meet the highest levels of required military readiness in order to respond to naval opponents. Alternative 2 reflects the maximum number of training and testing activities that could occur within a given year and assumes that the maximum level of activity would occur every year over a 5-year period. This allows for the greatest flexibility for the Navy to maintain readiness when considering potential changes in the national security environment, fluctuations in schedules, and anticipated in-theater demands.

The resources evaluated include air quality, sediments and water quality, vegetation, invertebrates, habitats, fishes, marine mammals, reptiles, birds, cultural resources, socioeconomic resources, and public health and safety.

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FOREWORD

The Draft Hawaii-Southern California Training and Testing (HSTT) Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS) was released for public review and comment 13 October 2017 through 12 December 2017. Changes in this Final EIS/OEIS reflect responses to all substantive comments made on the Draft EIS/OEIS during the public comment period as well as Navy refinements to the Proposed Action. Public comments are summarized, and their corresponding responses are provided in Appendix H, Public Comments and Responses.

While most sections in the EIS/OEIS were changed in some manner between the draft and final versions, many of those changes entailed minor modifications to improve clarity. The key changes between the HSTT Draft EIS/OEIS and Final EIS/OEIS follow.

- Chapter 1 (Purpose and Need):
  The description of the Purpose and Need was revised to explain that this EIS/OEIS was prepared to meet both the Navy's and the National Marine Fisheries Service's respective National Environmental Policy Act (NEPA) obligations and support the decisionmaking of both agencies.

- Chapter 2 (Description of Proposed Action and Alternatives):
  The description of the Hawaii Range Complex was revised to clarify and distinguish the Temporary Operating Area and the Hawaii Operating Area. The description of the Southern California portion of the HSTT Study Area was revised to better explain the components that make up the Study Area. All changes were to the descriptions only; no changes were made to the actual Study Area.

  Descriptions of some proposed training and testing activities were revised to more definitively describe the activity. The activities themselves did not change and did not require new analyses. The analyses conducted for the Draft EIS/OEIS remain valid for the Final EIS/OEIS.

  Descriptions of some standard operating procedures were revised to illustrate how the procedures provide benefits to environmental and cultural resources.

  The Navy added in the Final EIS/OEIS that it considered but eliminated an alternative based solely on geographic mitigation.

  The frequency of one training activity was decreased from the Draft to the Final EIS/OEIS: the Mine Neutralization Explosive Ordnance Disposal activity conducted in the Southern California Range Complex was reduced from 194 events per year and 970 over 5 years, to 170 per year and 850 over 5 years. Because the number of explosives used did not change, the analysis as described in the Draft EIS/OEIS remains valid.

- Section 3.0 (Introduction to Affected Environment and Environmental Consequences):
  In the Final EIS/OEIS, the Navy included additional detail about data sources utilized in the Marine Species Density Database, and added a description of the Navy's Acoustic Effects

Model used to estimate the number of marine mammals or sea turtles that could be affected by Navy sonar and explosives.

The number of testing air gun sources in Table 3.0-3 in the Draft EIS/OEIS did not reflect the number of sources that were analyzed. Table 3.0-3 in the Final EIS/OEIS shows the correct number of air gun sources that were quantitatively analyzed in both the Draft EIS/OEIS and the Final EIS/OEIS, 844 per year, 4,220 over 5 years.

The description of how vessel noise was analyzed was revised, and various tables and figures were updated.

Various tables were updated to reflect a more accurate accounting of quantities of military expended materials and other non-acoustic and explosive stressors associated with proposed training and testing activities. The changes, which included increases and decreases, were considered in the Final EIS/OEIS analysis, but did not result in changes to the conclusions reached in the Draft EIS/OEIS.

The description of fiber optic cables expended during training and testing activities was revised with more recent information.

The description of decelerators/parachutes was revised to reclassify the various sizes of decelerators/parachutes proposed for use. The new decelerator/parachute size classification was carried throughout all the resource sections for analysis.

- Section 3.1 (Air Quality):
  Additional information regarding attainment, National Ambient Air Quality Standards, and the General Conformity Evaluation was added in the Final EIS/OEIS. The Navy added a description of two islands that occur in the Study Area, but are included in the South Central Coast Air Basin. In the Final EIS/OEIS, the emissions tables were revised to present the data in an overall summary format, and comparisons to the baseline emissions were provided. The Prevention of Significant Deterioration Thresholds were updated in all applicable tables. Some emissions estimates were revised to correct minor calculation errors. All revisions were minor, and no conclusions were affected. The Record of Non-Applicability was signed by the Navy and included in Appendix C.
- Section 3.2 (Sediments and Water Quality):
  Changes were made to the description of sediment class sizes in the Affected Environment section to be consistent with a single, modern classification system. Minor adjustments to all map figures were made to ensure the figures are consistent in labeling and nomenclature with other sections in the Final EIS/OEIS. The Navy added clarification that some anchors used to moor seafloor devices may be left on the seafloor after the seafloor devices are recovered.
- Section 3.3 (Vegetation):
  A description of procedural mitigation measures was added to explain how those measures could benefit vegetation. The Essential Fish Habitat Determinations section was removed

from this section, with a complete summary provided in Chapter 6 (Regulatory Considerations).

- Section 3.4 (Marine Invertebrates):
  The General Background section was updated to include additional information on habitat use, movement and behavior, and climate change. Additional information was also added in the description of corals. The description of impacts from sound sources was revised with information from recent studies. No conclusions changed as a result of the new information. The Essential Fish Habitat Determinations section was removed from this section, with a complete summary provided in Chapter 6 (Regulatory Considerations).
- Section 3.5 (Marine Habitats):
  Figures depicting the bottom substrate compositions and artificial structures within the Study Area were updated. The analysis of impacts was revised to provide updated areas potentially affected by explosives or military expended materials, and a description of mitigation measures was provided, explaining how the measures could benefit important habitats from these activities.

  Impact footprint estimates were revised as calculation errors were discovered. All revisions were minor, and no conclusions were affected. Additionally, the habitats database was updated to include recently published data sources including both mapped polygon and point data. The Essential Fish Habitat Determinations section was removed from this section, with a complete summary provided in Chapter 6 (Regulatory Considerations).
- Section 3.6 (Fishes):
  The General Background section was updated in several places with new information that wasn't available when the Draft EIS/OEIS was released. The ESA status of oceanic whitetip shark and giant manta ray were updated from proposed threatened to listed as threatened based on NMFS Final Rules that were published after the Draft EIS/OEIS. In addition, the Pacific bluefin tuna was removed from the candidate species list. The Acoustic Stressors discussion was updated to include new information from recent studies and the ESA analysis and conclusions were updated in the Final EIS/OEIS to correspond with the results of recent ESA consultations. The Essential Fish Habitat Determinations section was removed from this section, with a complete summary provided in Chapter 6 (Regulatory Considerations). In addition, injury criteria for explosives were revised based on best available information to more accurately reflect the risk to fishes.
- Section 3.7 (Marine Mammals):
  Marine mammal species listing status, abundance estimates, general threats discussions, and environmental consequences sections were updated based on the most recent stock assessment reports and new literature. Following the release of the Draft EIS/OEIS, NMFS designated critical habitat for the main Hawaiian Islands insular false killer whale distinct population segment. In the Final EIS/OEIS, the Navy analyzed potential impacts to this newly designated critical habitat. The Final EIS/OEIS also included updates to the critical habitat

discussions and determinations for Hawaiian monk seal based on new information that some anchors associated with bottom-placed instruments are not recovered. Updated information on entanglement stressors described in Section 3.0.5.3 (Identification of Stressors for Analysis) were incorporated into the analysis. Updates to mitigation measures (Chapter 5) were also included as a result of consultations under the Marine Mammal Protection Act (MMPA) and ESA.

- Section 3.8 (Reptiles):
  The General Background section was updated in several places with new information that wasn't available when the Draft EIS/OEIS was released. The Acoustic Stressors and Explosive Stressors discussion and analysis sections were updated to include new information.
- Section 3.9 (Birds):
  The General Background section was updated to include additional information on wind energy development and marine debris. The ESA status of the band-rumped storm petrel (Hawaii distinct population segment) was corrected from a candidate species to endangered. ESA conclusions were updated to reflect the Biological Assessment and section 7 consultation with USFWS. Additional hearing references were added. Potential for helicopter noise exposure was clarified, and additional information about animal flight altitude was added for assessing acoustic exposures.
- Section 3.10 (Cultural Resources):
  Cultural practices and beliefs shared by participants at the National Historic Preservation Act Section 106 consultation meetings have been added in the Final EIS/OEIS. Minor corrections and edits were made, where applicable.
- Section 3.11 (Socioeconomic Resources):
  Updates to data on recreational fisheries, commercial fisheries, commercial transportation and shipping, and tourism were made to incorporate the most recent available annual data, such as the amount and value of commercial landings, the volume of goods processed at commercial ports, and the economic contribution of tourism to the states' economies.
- Section 3.12 (Public Health and Safety):
  Updates and edits were made with regard to the latest regulations and standard operating procedures that benefit public health and safety.
- Chapter 4 (Cumulative Impacts):
  Non-substantive changes were made throughout Chapter 4 (Cumulative Impacts) to maintain alignment and consistency with updates to Chapters 1-3 (Purpose and Need, Description of Proposed Action and Alternatives, and Affected Environment and Environmental Consequences), to reflect the availability of updated data, and to correct minor editorial issues.

  Additionally, the past, present, and reasonably foreseeable projects and industry information described in Table 4.2-1 was updated where new information was available, and this new information was incorporated into the cumulative analysis for each resource as warranted.

Minor changes were made with respect to the cumulative effects analysis of specific resources. All other changes to the cumulative analysis of specific resources incorporate relevant changes that were made to corresponding resource analyses in Chapter 3 (see bullet list, above).

- Chapter 5 (Mitigation):
  Based on its ongoing analysis of the best available science and potential mitigation measures, the Navy determined it would be practical to implement additional mitigation measures to enhance protection of marine mammals to the maximum extent practicable. The new mitigation measures are detailed in the Final EIS/OEIS and include: (1) refining the geographic mitigation requirements in the Hawaii Range Complex and Southern California portion of the HSTT Study Area, (2) adding a requirement to survey for marine mammals and ESA-listed species after the completion of explosive activities in the vicinity of where detonations occurred (when practical), and (3) requiring additional platforms already participating in explosive activities to support observing for applicable biological resources before, during, and after the activity.

- Chapter 6 (Regulatory Considerations):
  The Status of Compliance information within Table 6.1-1 was updated to reflect the most current status of the Navy's compliance with the various laws, executive orders, and international standards. Similarly, updates were made to reflect the updated status of Coastal Zone Management Act compliance with Hawaii and California, National Marine Sanctuaries Act compliance, National Historic Preservation Act compliance, and Magnuson-Stevens Fishery Conservation and Management Act compliance.

- Chapter 7 (List of Preparers):
  Changes were made to update the List of Preparers based on changes in personnel working on the project.

- Chapter 8 (Public Involvement):
  Information regarding the public participation process, related to the release of the Draft EIS/OEIS, public meetings held, and the public comments received on the Draft EIS/OEIS comments were added.

- Appendix A (Navy Activity Descriptions):
  Changes were made to improve descriptions of proposed activities and to correct errors.

- Appendix B (Activity Stressor Matrices):
  Changes were made to reflect corrections made to Appendix A (Navy Activity Descriptions), and to correct errors.

- Appendix C (Air Quality Emission Calculations and Record of Non-Applicability):
  The example emissions calculations and Record of Non-Applicability were updated based on corrections to errors.
- Appendix D (Acoustic and Explosive Concepts):
  A reference to a Navy technical report was updated to the final report.
- Appendix E (Estimated Marine Mammal and Sea Turtle Impacts from Exposure to Acoustic and Explosive Stressors Under Navy Training and Testing Activities):
  Changes were made to the exposure numbers of humpback whale, Cuvier's beaked whales, and Mesoplodon spp. due to corrections in acoustic modeling spreadsheets/calculations. No other changes were made.
- Appendix F (Military Expended Material and Direct Strike Impact Analysis):
  Changes were made to the military expended materials tables and the benthic substrate impact tables to correct errors made in the accounting of these materials.
- Appendix G (Federal Register Notices):
  Additional Federal Register Notices since the public release of the Draft EIS/OEIS were added.
- Appendix H (Public Comment Responses):
  This Appendix was added since the release of the Draft EIS/OEIS and includes an explanation of the public comment process for the Draft EIS/OEIS, list of agencies and organizations that provided comments, and a table containing the comments received and the Navy's responses.
- Appendix I (Geographic Information System Data Sources):
  Geographic Information System data features and source information was updated.
- Appendix J (Agency Correspondence):
  Agency correspondence received since the public release of the Draft EIS/OEIS is included.
- Appendix K (Geographic Mitigation Assessment):
  The mitigation areas to be implemented in the HSTT Study Area were revised and simplified. The appendix was fully revised to remove errors and clarify the Navy's approach to analyzing mitigation areas. The Final EIS/OEIS mitigation assessment in Appendix K includes additional areas that were proposed in comments received during the public comment process and areas proposed during the Coastal Zone Management Act consultation process.

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EXECUTIVE SUMMARY

ES.1 Introduction

The United States (U.S.) Department of the Navy (Navy) prepared this Environmental Impact Statement (EIS)/Overseas EIS (OEIS) to assess the potential environmental impacts associated with two categories of military readiness activities: training and testing. Collectively, the at-sea areas in this EIS/OEIS are referred to as the Hawaii-Southern California Training and Testing (HSTT) Study Area (Study Area) (Figure ES-1). The Navy also prepared this EIS/OEIS to comply with the National Environmental Policy Act (NEPA) and Executive Order 12114.

Major conflicts, terrorism, lawlessness, and natural disasters all have the potential to threaten the national security of the United States. United States' national security, prosperity, and vital interests are increasingly tied to other nations because of the close relationships between the United States and other national economies. The Navy carries out training and testing activities to be able to protect the United States against its enemies, as well as to protect and defend the rights of the United States and its allies to move freely on the oceans. Training and testing activities that prepare the Navy to fulfill its mission to protect and defend the United States and its allies potentially impact the environment. These activities may trigger legal requirements identified in many U.S. federal environmental laws, regulations, and executive orders.

ES.2 Purpose and Need

The Navy and National Marine Fisheries Service (NMFS) (as a cooperating agency) have coordinated from the outset and developed this document to meet each agency's distinct NEPA obligations and support the decision making of both agencies. The purpose of the Proposed Action is to ensure that the Navy meets its mission under Title 10 United States Code Section 5062, which is to maintain, train, and equip combat-ready naval forces capable of winning wars, deterring aggression, and maintaining freedom of the seas. This mission is achieved in part by conducting training and testing within the Study Area. NMFS's purpose is to evaluate the Navy's proposed action pursuant to NMFS's authority under the Marine Mammal Protection Act (MMPA), and to make a determination whether to issue incidental take regulations and Letters of Authorization, including any conditions needed to meet the statutory mandates of the MMPA.

ES.3 Scope and Content of the Environmental Impact Statement/Overseas Environmental Impact Statement

In this EIS/OEIS, the Navy assessed military readiness activities that could potentially impact human and natural resources, especially marine mammals, sea turtles, and other marine resources. The range of alternatives includes a No Action Alternative and other reasonable courses of action. Direct, indirect, cumulative, short-term, long-term, irreversible, and irretrievable impacts were also analyzed. Data sets used for analysis were considered across the full spectrum of Navy training and testing for the foreseeable future. For the purposes of analysis and presentation within this EIS/OEIS, data was organized and evaluated in 1-year and 5-year increments. Based upon current knowledge and the proposed training and testing, the Navy does not reasonably foresee a change to the Navy's direct and indirect impact conclusions across other time frames (ex., 2, 7, 10 years). The Navy is the lead agency for the Proposed Action and is responsible for the scope and content of this EIS/OEIS. NMFS is a cooperating agency pursuant to 40 Code of Federal Regulations (CFR) section 1501.6 because of its expertise and

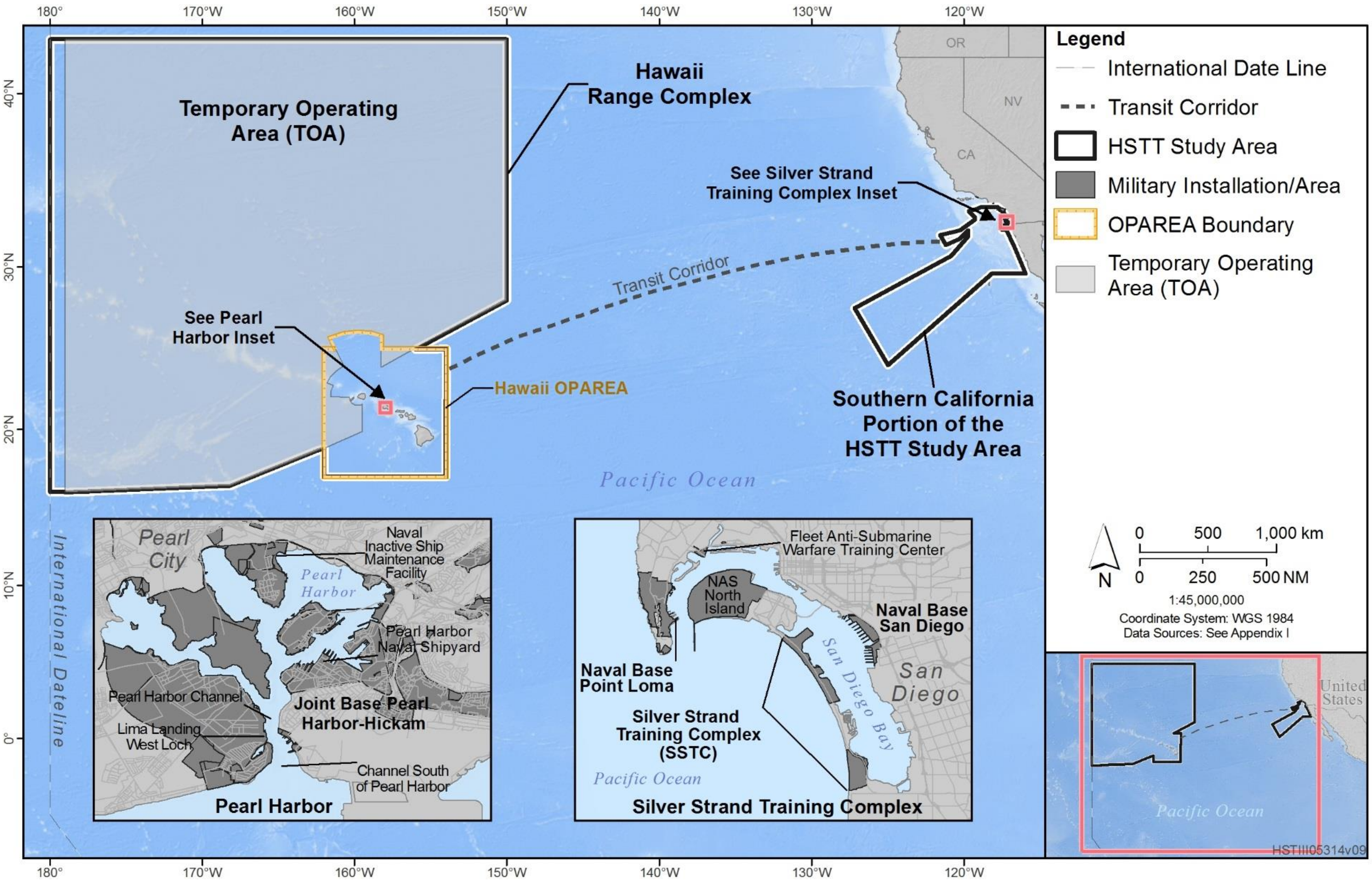

Figure ES-1: Hawaii-Southern California Training and Testing Study Area

Notes: HSTT = Hawaii-Southern California Training and Testing, NAS = Naval Air Station regulatory authority over certain marine resources. Additionally, NMFS plans to use this document as its NEPA documentation for the rule-making process under the MMPA.

In accordance with the Council on Environmental Quality Regulations, 40 CFR section 1505.2, the Navy will issue a Record of Decision. The decision will be based on factors analyzed in this EIS/OEIS, including military training and testing objectives, best available science and modeling data, potential environmental impacts, and public interest.

ES.3.1 National Environmental Policy Act

Federal agencies are required under NEPA to examine the environmental impacts of their proposed actions within the United States and its territories. An EIS is a detailed public document that provides an assessment of the potential effects that a major federal action might have on the human environment, which includes the natural environment. The Navy undertakes environmental planning for major Navy actions occurring throughout the world in accordance with applicable laws, regulations, and Executive Orders. Presidential Proclamation 5928, issued December 27, 1988, extended the exercise of U.S. sovereignty and jurisdiction under international law to 12 nautical miles (NM); however, the proclamation expressly provides that it does not extend or otherwise alter existing federal law or any associated jurisdiction, rights, legal interests, or obligations. Thus, as a matter of policy, the Navy analyzes environmental effects and actions within 12 NM under NEPA (an EIS).

ES.3.2 Executive Order 12114

This OEIS has been prepared in accordance with Executive Order 12114 (44 *Federal Register* 1957) and Navy implementing regulations in 32 CFR part 187, *Environmental Effects Abroad of Major Department of Defense Actions*. An OEIS is required when a proposed action and alternatives have the potential to significantly harm the environment of the global commons. The global commons are defined as geographical areas outside the jurisdiction of any nation and include the oceans outside of the territorial limits (more than 12 NM from the coast) and Antarctica but do not include contiguous zones and fisheries zones of foreign nations (32 CFR section 187.3). The EIS and OEIS have been combined into one document, as permitted under NEPA and Executive Order 12114, to reduce duplication.

ES.3.3 Marine Mammal Protection Act

The MMPA of 1972 (16 U.S. Code [U.S.C.] section 1361 et seq.) established, with limited exceptions, a moratorium on the “taking” of marine mammals in waters or on lands under U.S. jurisdiction. The act further regulates “takes” of marine mammals on the high seas by vessels or persons subject to U.S. jurisdiction. The term “take,” as defined in section 3 (16 U.S.C. section 1362(13)) of the MMPA, means “to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal.” “Harassment” was further defined in the 1994 amendments to the MMPA, which provided two levels of harassment: Level A (potential injury) and Level B (potential behavioral disturbance).

The MMPA directs the Secretary of Commerce (as delegated to NMFS) to allow, upon request, the incidental, but not intentional, taking of small numbers of marine mammals by U.S. citizens who engage in a specified activity (other than commercial fishing) within a specified geographical region if NMFS finds that the taking will have a negligible impact on the species or stock(s), and will not have an immitigable adverse impact on the availability of the species or stock(s) for subsistence uses (where relevant). The authorization must set forth the permissible methods of taking, other means of effecting the least practicable adverse impact on the species or stock and its habitat, and on the availability of the species or stock for subsistence uses (where relevant), and requirements pertaining to the monitoring and reporting of such taking.

The National Defense Authorization Act of Fiscal Year 2004 (Public Law 108-136) amended the definition of harassment and removed the "small numbers" provision as applied to military readiness activities or scientific research activities conducted by or on behalf of the federal government consistent with section 104(c)(3) (16 U.S.C. section 1374 [c][3]). The Fiscal Year 2004 National Defense Authorization Act adopted the definition of "military readiness activity" as set forth in the Fiscal Year 2003 National Defense Authorization Act (Public Law 107-314). A "military readiness activity" is defined as "all training and operations of the Armed Forces that relate to combat" and "the adequate and realistic testing of military equipment, vehicles, weapons, and sensors for proper operation and suitability for combat use." Since the Proposed Action involves conducting military readiness activities, the relevant definition of harassment is any act that

- injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild ("Level A harassment") or
- disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering to a point where such behavioral patterns are abandoned or significantly altered ("Level B harassment") [16 U.S.C. section 1362(18)(B)(i) and (ii)].

ES.3.4 ENDANGERED SPECIES ACT

The Endangered Species Act (ESA) of 1973 (16 U.S.C. section 1531 et seq.) provides for the conservation of endangered and threatened species, and of the ecosystems on which they depend. The Act defines an "endangered" species as a species in danger of extinction throughout all or a significant portion of its range. A "threatened" species is one that is likely to become endangered within the foreseeable future throughout all or a significant portion of its range. The U.S. Fish and Wildlife Service (USFWS) and NMFS jointly administer the ESA and are responsible for listing species as threatened or endangered and for designating critical habitat for listed species. Section 7(a)(2) requires each federal agency to ensure that any action it authorizes, funds, or carries out is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of habitat of such species. When a federal agency's action "may affect" a listed species, that agency is required to consult with the Service (NMFS or USFWS) that has jurisdiction over the species in question (50 CFR section 402.14(a)). Under the terms of section 7(b)(4) and section 7(o)(2) of the ESA, taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the act provided that such taking complies with the terms and conditions of an Incidental Take Statement.

ES.3.5 ADDITIONAL ENVIRONMENTAL REQUIREMENTS CONSIDERED

The Navy must comply with all applicable federal environmental laws, regulations, and Executive Orders, including, but not limited to, those listed below. Further information on Navy compliance with these and other environmental laws, regulations, and Executive Orders can be found in Chapter 1 (Purpose and Need), Chapter 3 (Affected Environment and Environmental Consequences), and Chapter 6 (Regulatory Considerations).

- Abandoned Shipwreck Act
- Antiquities Act

- Clean Air Act
- Clean Water Act
- Coastal Zone Management Act
- Magnuson-Stevens Fishery Conservation and Management Act
- Migratory Bird Treaty Act
- National Historic Preservation Act
- National Marine Sanctuaries Act
- Rivers and Harbors Act
- Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations
- Executive Order 12962, Recreational Fisheries
- Executive Order 13045, Protection of Children from Environmental Health Risks and Safety Risks
- Executive Order 13089, Coral Reef Protection
- Executive Order 13112, Invasive Species
- Executive Order 13158, Marine Protected Areas
- Executive Order 13175, Consultation and Coordination with Indian Tribal Governments
- Executive Order 13783, On Promoting Energy Independence and Economic Growth
- Executive Order 13834, Efficient Federal Operations
- Executive Order 13840, Ocean Policy to Advance the Economic, Security, and Environmental Interests of the United States

ES.4 Proposed Action and Alternatives

The U.S. Navy proposes to conduct military readiness training activities (hereinafter referred to as "training") and research, development, testing, and evaluation (hereinafter referred to as "testing") activities in the HSTT Study Area, as represented in Figure ES-1. These military readiness activities include the use of active sonar and explosives at sea off the coasts of Hawaii and Southern California, on the high seas where training and sonar testing and maintenance may occur during vessel transit between these areas, in the Temporary Operating Area north and west of the Hawaii Operating Area, and at select Navy pierside and harbor locations. These military readiness activities are generally consistent with those analyzed in the HSTT EIS/OEIS completed in December 2013 and are representative of training and testing that the Navy has been conducting in the HSTT Study Area for decades.

The Navy's entire suite of mitigation measures was developed in coordination with NMFS. The Action Alternatives and mitigation measures meet both the Navy's and NMFS's purpose and need. The Navy will implement mitigation to avoid or reduce potential impacts of training and testing activities on environmental and cultural resources under both action alternatives (Alternative 1 [Preferred Alternative] and Alternative 2).

ES.4.1 No Action Alternative

Under the No Action Alternative, the Proposed Action would not take place (i.e., the Navy would not conduct proposed training and testing activities in the HSTT Study Area). For NMFS, denial of an application for an incidental take authorization constitutes the NMFS No Action Alternative, which is consistent with NMFS' statutory obligation under the MMPA to grant or deny requests for take incidental to specified activities. The resulting environmental effects from taking no action will be compared with the effects of the Proposed Action.

ES.4.2 Alternative 1

Alternative 1 is the Preferred Alternative.

ES.4.2.1 Training

Under this alternative, the Navy proposes to conduct military readiness training activities into the reasonably foreseeable future, as necessary to meet current and future readiness requirements. These military readiness training activities include new activities as well as activities subject to previous analysis that are currently ongoing and have historically occurred in the Study Area. These activities account for force structure (organization of ships, weapons, and personnel) changes and include training with new aircraft, vessels, unmanned/autonomous systems, and weapon systems that will be introduced to the fleets after December 2018. The numbers and locations of all proposed training activities are provided in Table 2.6-1, in Section 2.6.1 (Proposed Training Activities).

Alternative 1 reflects a representative year of training to account for the natural fluctuation of training cycles and deployment schedules that generally limit the maximum level of training from occurring year after year in any 5-year period. Using a representative level of activity rather than a maximum tempo of training activity in every year has reduced the amount of hull-mounted mid-frequency active sonar estimated to be necessary to meet training requirements. Both unit-level training and major training exercises are adjusted to meet this representative year.

By using a representative level of training activity rather than a maximum level of training activity in every year, this alternative incorporates a degree of risk that the Navy will not have sufficient capacity to conduct the necessary training to meet future national emergencies.

ES.4.2.2 Testing

Alternative 1 reflects a level of testing activities to be conducted into the reasonably foreseeable future, with adjustments that account for changes in the types and tempo (increases or decreases) of testing activities to meet current and future military readiness requirements. This alternative includes the testing of new platforms, systems, and related equipment that will be introduced after December 2018. The majority of testing activities that would be conducted under this alternative are the same as or similar as those conducted currently or in the past. This alternative includes the testing of some new systems using new technologies and takes into account inherent uncertainties in this type of testing.

Under Alternative 1, the Navy proposes an annual level of testing that reflects the fluctuations in testing programs by recognizing that the maximum level of testing will not be conducted each year. This alternative contains a more representative level of activities, but includes years of a higher maximum amount of testing to account for these fluctuations. This alternative would not include the contingency for augmenting some weapon system tests, which would increase levels of annual testing of anti-submarine warfare and mine warfare systems, and presumes a typical level of readiness requirements. All proposed testing activities are listed in Table 2.6-2 through Table 2.6-5, in Section 2.6.2 (Testing).

ES.4.3 Alternative 2

ES.4.3.1 Training

As under Alternative 1, Alternative 2 includes new and ongoing activities. Under Alternative 2, training activities are based on requirements established by the Optimized Fleet Response Plan. Under this alternative, the Navy would be enabled to meet the highest levels of required military readiness by conducting the majority of its training live at sea, and by meeting unit-level training requirements using dedicated, discrete training events, instead of combining them with other training activities as described in Alternative 1. The numbers and locations of all proposed training activities are provided in Table 2.6-1, in Section 2.6.1 (Proposed Training Activities).

Alternative 2 reflects the maximum number of training activities that could occur within a given year, and assumes that the maximum level of activity would occur every year over any 5-year period. This allows for the greatest flexibility for the Navy to maintain readiness when considering potential changes in the national security environment, fluctuations in training and deployment schedules, and anticipated in-theater demands. Both unit-level training and major training exercises are assumed to occur at a maximum level every year.

ES.4.3.2 Testing

Alternative 2 entails a level of testing activities to be conducted into the reasonably foreseeable future and includes the testing of new platforms, systems, and related equipment that will be introduced after December 2018. The majority of testing activities that would be conducted under this alternative are the same as or similar to those conducted currently or in the past.

Alternative 2 would include the testing of some new systems using new technologies, taking into account the potential for delayed or accelerated testing schedules, variations in funding availability, and innovations in technology development. To account for these inherent uncertainties in testing, this alternative assumes that the maximum annual testing efforts predicted for each individual system or program could occur concurrently in any given year. This alternative also includes the contingency for augmenting some weapon systems tests in response to potential increased world conflicts and changing Navy leadership priorities as the result of a direct challenge from a naval opponent that possesses near-peer capabilities. Therefore, this alternative includes the provision for higher levels of annual testing of certain anti-submarine warfare and mine warfare systems to support expedited delivery of these systems to the fleet. All proposed testing activities are listed in Table 2.6-2 through Table 2.6-5, in Section 2.6.2 (Testing).

ES.5 SUMMARY OF ENVIRONMENTAL EFFECTS

Environmental effects which might result from implementing the Navy's Proposed Action or alternatives have been analyzed in this EIS/OEIS. Resource areas analyzed include air quality, sediments and water quality, vegetation, invertebrates, habitats, fishes, marine mammals, reptiles, birds, cultural resources, socioeconomic resources, and public health and safety. Table ES-1 provides a comparison of the potential environmental impacts of the No Action Alternative, Alternative 1 (Preferred Alternative), and Alternative 2.

This Final EIS/OEIS covers similar types of Navy training and testing activities in the same study area analyzed in the 2013 HSTT Final EIS/OEIS. The Navy has re-evaluated impacts from these ongoing activities in existing ranges and operating areas (OPAREAs) offshore of Hawaii and Southern California, including activities that occur during transit between these areas. The Navy analyzed new or changing military readiness activities into the reasonably foreseeable future based on evolving operational requirements, including those associated with new platforms and systems not previously analyzed. Additionally, the Navy thoroughly reviewed and incorporated the best available science relevant to analyzing the environmental impacts of the proposed activities. Changes from the 2013 HSTT Final EIS/OEIS include the following:

ES.5.1 Sonar and Explosives

The Navy's refined analysis of anti-submarine warfare activities results in reduced levels of active sonar analyzed. The new presentation of anti-submarine warfare activities more accurately reflects the variability in the number of certification related events (e.g., Composite Training Exercise) conducted per year due to varying deployment schedules and ship availabilities. This new analysis also better accounts for a portion of unit level surface ship tracking exercise requirements being met during coordinated/integrated anti-submarine warfare training and major training exercises, or through synthetic training. These refinements to the analysis result in fewer hours of acoustic sources, such as hull-mounted mid-frequency active acoustic systems, when estimating marine mammal exposures from training events.

This Final EIS/OEIS supports the Navy's increased focus on live training to meet evolving surface warfare challenges. This results in a proposed increase in levels of Air-to-Surface Warfare activities and an increased reliance on the use of non-explosive and explosive rockets, missiles, and bombs.

The number of Sinking Exercises proposed by the Navy has been reduced to reflect expected availability of Sinking Exercise targets.

Increases in training for maritime security operations (e.g., drug interdiction, anti-piracy) are proposed in Southern California to ensure Sailors are prepared to meet this important mission.

The sonar bin list has been updated/refined to reflect new active sonar sources, such as high-frequency imaging sonars and broadband sound sources proposed for testing and experimentation. Similarly, specific existing bins were refined to better reflect testing realism in the analysis.

The majority of platforms, weapons and systems that were proposed for testing during the 2013–2018 timeframe are the same or very similar to those proposed for testing in the future. However, the Navy projects testing of some platforms, weapons and systems will increase, while others will decrease, as compared to the testing requirements that were proposed for the 2013–2018 timeframe. In comparison, the Navy is projecting a net increase in testing systems that use sonar and a net decrease for explosives use, as proposed under Alternative 1 of this EIS/OEIS.

ES.5.2 Acoustic and Explosive Analysis

Improvements have been made to modeling explosive sources to optimize the analysis process and data handling. Statistical variability in the abundance of marine species was added to the marine species distribution process. The availability of additional systematic survey data as well as improvements to habitat modeling methods used to estimate species density resulted in substantial improvements to the species distribution. Marine species criteria and thresholds were also updated based on NMFS marine mammal criteria for permanent and temporary threshold shift for sonar and other transducers, pile driving, air guns and explosives. The Navy also used the best available science from the large number of behavioral response studies that have been conducted to-date to develop updated behavioral response functions.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2

Resource Category	*Summary of Impacts*
Section 3.1 Air Quality	The Navy considered all potential stressors that air quality could be exposed to from the Proposed Action. The following conclusions have been reached for the project alternatives: **No Action Alternative:** • Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Discontinuing training and testing activities under the No Action Alternative would not measurably improve air quality in the Study Area. **Alternative 1 (Preferred Alternative):** • Criteria air pollutants: The emission of criteria pollutants resulting from activities in the Study Area would not cause a violation or contribute to an ongoing violation of the National Ambient Air Quality Standards. **Alternative 2:** • Criteria air pollutants: The emission of criteria pollutants resulting from activities associated with Alternative 2 would increase slightly over emissions from Alternative 1; however, they would not cause a violation or contribute to an ongoing violation of the National Ambient Air Quality Standards.
Section 3.2 Sediments and Water Quality	The Navy considered all potential stressors that sediments and water quality could be exposed to from the Proposed Action. The following conclusions have been reached for the project alternatives: **No Action Alternative:** • Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. The stressors potentially impacting sediments and water quality (e.g., explosives, explosive byproducts, metals) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities. **Alternative 1 (Preferred Alternative):** • Explosives and explosives byproducts: Impacts from explosives and explosives byproducts would be short-term and local. Impacts from unconsumed explosives and constituent chemical compounds would be minimal and limited to the area adjacent to the munition. Explosives and constituent compounds could persist in the environment depending on the integrity of the undetonated munitions casing and the physical conditions on the seafloor where the munition resides. Chemical and physical changes to sediments and water quality, as measured by the concentrations of contaminants or other anthropogenic compounds, may be detectable and would be below applicable regulatory standards for determining effects on biological resources and habitats.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	***Summary of Impacts***
Section 3.2 Sediments and Water Quality (continued)	• Chemicals other than explosives: Impacts from other chemicals not associated with explosives would be both short term and long term depending on the chemical and the physical conditions on the seafloor where the source of the chemicals resides. Impacts would be minimal and localized to the immediate area surrounding the source of the chemical release. • Metals: Impacts from metals would be minimal, long term, and dependent on the metal and the physical conditions on the seafloor where the metal object (e.g., non-explosive munition) resides. Impacts would be localized to the area adjacent to the metal object. Concentrations of metal contaminants near the expended material or munition may be measurable and are likely to be similar to the concentrations of metals in sediments from nearby reference locations. • Other military expended materials: Impacts from other expended materials not associated with munitions would be both short-term and long-term depending on the material and the physical conditions on the seafloor where the material resides. Impacts would be localized to the immediate area surrounding the material. Chemical and physical changes to sediments and water quality, as measured by the concentrations of contaminants or other anthropogenic compounds near the expended material, are not likely to be detectable and would be similar to the concentrations of chemicals and material residue from nearby reference locations. **Alternative 2:** • Explosives and explosives byproducts: Impacts from explosives under Alternative 2 for training and testing activities would be as described under Alternative 1. • Chemicals other than explosives: Impacts from other chemicals not associated with explosives under Alternative 2 would be as described under Alternative 1 despite a small increase in expended materials. • Metals: The increase in the use of munitions and other objects containing metals would increase the amount of metals introduced into the seafloor environment over the amount in Alternative 1. However, the increase is not a substantial increase over the number of munitions used under Alternative 1 and would not alter the conclusions presented for Alternative 1. • Other military expended materials: The number of other expended materials would increase slightly. The additional expended materials are non-explosive sonobuoys and their small decelerator/parachutes. The small increase in plastics and metals in the additional expended materials would not change the conclusions presented under Alternative 1. Therefore, impacts from other materials would be expected to be the same as those analyzed under Alternative 1.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	***Summary of Impacts***
Section 3.3 Vegetation	The Navy considered all potential stressors that vegetation could be exposed to from the Proposed Action. The following conclusions have been reached for the project alternatives: **No Action Alternative:** • Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various stressors would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities. **Alternative 1 (Preferred Alternative):** • Explosives: Explosives could affect vegetation by destroying individuals or damaging parts of individuals; however, there would be no persistent or large-scale effects on the growth, survival, distribution, or structure of vegetation. • Physical Disturbance and Strike: Physical disturbance and strike could affect vegetation by destroying individuals or damaging parts of individuals; however, there would be no persistent or large-scale effects on the growth, survival, distribution, or structure of vegetation. • Secondary: Project effects from secondary stressors such as sediment, water, or air quality would be minor, temporary, and localized, and could have small-scale secondary effects on vegetation; however, there would be no persistent or large-scale effects on the growth, survival, distribution, or structure of vegetation. **Alternative 2:** • Explosives: Although activities under Alternative 2 occur at a higher rate and frequency relative to Alternative 1, physical disturbance and strike impacts experienced by individuals or populations from explosives under Alternative 2 are not expected to be meaningfully different from those described under Alternative 1. Therefore, impacts associated with training and testing activities under Alternative 2 are the same as Alternative 1. • Physical Disturbance and Strike: Impacts from physical disturbance and strike under Alternative 2 would increase slightly compared to those of Alternative 1 because of a small increase in proposed activities, but the difference in impacts would be undetectable. • Secondary: Secondary impacts under Alternative 2 would increase slightly compared to those of Alternative 1 because of a small increase in activities and expended materials, but the difference would not result in substantive changes.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	*Summary of Impacts*
Section 3.4 Invertebrates	The Navy considered all potential stressors that invertebrates could be exposed to from the Proposed Action. The following conclusions have been reached for the project alternatives: **<u>No Action Alternative</u>:** • Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various stressors (e.g., military expended materials other than munitions) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities. **<u>Alternative 1 (Preferred Alternative)</u>:** • <u>Acoustics</u>: Invertebrates could be exposed to noise from the proposed training and testing activities. However, available information indicates that invertebrate sound detection is primarily limited to low-frequency (less than 1 kilohertz [kHz]) particle motion and water movement that diminishes rapidly with distance from a sound source. The expected impact of noise on invertebrates is correspondingly diminished and mostly limited to offshore surface layers of the water column where only zooplankton, squid, and jellyfish are prevalent mostly at night when training and testing occur less frequently. Invertebrate populations are typically lower offshore, where most training and testing occurs, than inshore due to the scarcity of habitat structure and comparatively lower nutrient levels. Exceptions occur at nearshore and inshore locations where occasional pierside sonar, air gun, or pile driving actions occur near relatively resilient soft bottom or artificial substrate communities. Because the number of individuals affected would be small relative to population numbers, population-level impacts are unlikely. • <u>Explosives</u>: Explosives produce pressure waves that can harm invertebrates in the vicinity of where they typically occur: mostly offshore surface waters where zooplankton, squid, and jellyfish are prevalent mostly at night when training and testing with explosives do not typically occur. Invertebrate populations are generally lower offshore than inshore due to the scarcity of habitat structure and comparatively lower nutrient levels. Exceptions occur where explosives are used on the bottom within nearshore or inshore waters on or near sensitive live hard bottom communities. Soft bottom communities are resilient to occasional disturbances. Due to the relatively small number of individuals affected, population-level impacts are unlikely. • <u>Energy</u>: The proposed activities would produce electromagnetic energy that briefly affects a very limited area of water, based on the relatively weak magnetic fields and mobile nature of the stressors. Whereas some invertebrate species can detect magnetic fields, the effect has only been documented at much higher field strength than what the proposed activities generate. High-energy lasers can damage invertebrates. However, the effects are limited to surface waters where relatively few invertebrate species occur (e.g., zooplankton, squid, jellyfish), mostly at night when actions do not typically occur, and only when the target is missed. Due to the relatively small number of individuals that may be affected, population-level impacts are unlikely.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	***Summary of Impacts***
Section 3.4 Invertebrates (continued)	• Physical Disturbance and Strike: Invertebrates could experience physical disturbance and strike impacts from vessels and in-water devices, military expended materials, seafloor devices, and pile driving. Most risk occurs offshore (where invertebrates are less abundant) and near the surface where relatively few invertebrates occur during the day when actions are typically occurring. The majority of expended materials are used in areas far from nearshore and inshore bottom areas where invertebrates are the most abundant. Exceptions occur for actions taking place within inshore and nearshore waters over primarily soft bottom communities, such as related to vessel transits, inshore and nearshore vessel training, nearshore explosive ordnance disposal training, operation of bottom-crawling seafloor devices, and pile driving. Invertebrate communities in affected soft bottom areas are naturally resilient to occasional disturbances. Accordingly, population-level impacts are unlikely. • Entanglement: Invertebrates could be entangled by various expended materials (wires, cables, decelerators/parachutes, biodegradable polymer). Most entanglement risk occurs in offshore areas where invertebrates are relatively less abundant. The risk of entangling invertebrates is minimized by the typically linear nature of the expended structures (e.g., wires, cables), although decelerators/parachutes have mesh that could pose a risk to those invertebrates that are large and slow enough to be entangled (e.g., jellyfish). Deep-water coral could also be entangled by drifting decelerators/parachutes, but co-occurrence is highly unlikely given the extremely sparse coverage of corals in the deep ocean. Accordingly, population-level impacts are unlikely. • Ingestion: Small expended materials and material fragments pose an ingestion risk to some invertebrates. However, most military expended materials are too large to be ingested, and many invertebrate species are unlikely to consume an item that does not visually or chemically resemble its natural food. Exceptions occur for materials fragmented by explosive charges or weathering, which could be ingested by filter- or deposit-feeding invertebrates. Ingestion of such materials would likely occur infrequently, and only invertebrates located very close to the fragmented materials would potentially be affected. Furthermore, the vast majority of human deposited ingestible materials in the ocean originate from non-military sources. Accordingly, population-level impacts are unlikely. • Secondary: Secondary impacts on invertebrates are possible via changes to habitats (sediment or water) and to prey availability due to explosives, explosives byproducts, unexploded munitions, metals, and toxic expended material components. Other than bottom-placed explosives, the impacts are mostly in offshore waters where invertebrates are less abundant. The impacts of occasional bottom-placed explosives are mostly limited to nearshore soft bottom habitats that recover quickly from disturbance. Following detonation, concentrations of explosive byproducts are rapidly diluted to levels that are not considered toxic to marine invertebrates. Furthermore, most explosive byproducts are common seawater constituents. Contamination leaching from unexploded munitions is likely inconsequential because the material has low solubility in seawater and is slowly delivered to the water column. Heavy metals and chemicals such as unspent propellants can reach harmful levels around stationary range targets but are not likely in open waters where proposed action targets are typically mobile or temporarily stationary.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	*Summary of Impacts*
Section 3.4 Invertebrates (continued)	**Alternative 1 (Preferred Alternative) (continued):** • Secondary (continued): Accordingly, overall impacts of secondary stressors on widespread invertebrate populations are not likely. Impacts due to decreased availability of prey items (fish and other invertebrates) would likely be undetectable. **Alternative 2:** • Acoustics: Potential impacts on invertebrates would be similar to those discussed for training and testing activities under Alternative 1. The only difference in sonar and other transducer use between Alternatives 1 and 2 is that the number of sonar hours used would be greater under Alternative 2. Air guns and pile driving impacts would be the same under Alternative 2. Potential impacts resulting from vessel noise would be similar to those discussed for activities under Alternative 1. Vessel use in the Study Area would increase by a very small amount (about 1 percent). The only difference in weapons noise impacts between Alternatives 1 and 2 is that the number of munitions used would be greater under Alternative 2. While the types of expected impacts on any individual invertebrate or group of invertebrates capable of detecting sounds produced during training and testing activities would remain the same, more animals could be affected. • Explosives: The locations and number of events involving explosives that could impact invertebrates would be similar to Alternative 1. Therefore, potential effects would be similar as described under Alternative 1. • Energy: The locations, number of events, and potential effects would be the same under Alternatives 1 and 2. • Physical Disturbance and Strike: Under Alternative 2, potential physical disturbance and strike impacts on invertebrates associated with training and testing activities would be similar to those discussed for activities under Alternative 1. The total area affected for all training and testing activities combined would increase by less than 1 percent under Alternative 2. There would be a very small increase in vessel and in-water device use in the Study Area. However, the difference would not result in substantive changes to the potential for or types of impacts on invertebrates. • Entanglement: There would be a small increase in the number of military expended materials associated with Alternative 2 activities. However, the increases are negligible and the potential impacts from wires and cables, decelerators/parachutes, and biodegradable polymer under Alternative 2 would be similar to that of Alternative 1. • Ingestion: Under Alternative 2, the locations and types of military expended materials used would be the same as those of Alternative 1. There would be an increase in the number of some items expended, such as targets, sonobuoys, bathythermograph equipment, and small decelerators/parachutes. This relatively small increase in the total number of items expended would not be expected to result in substantive changes to the type or degree of impacts on invertebrates. • Secondary: Secondary impacts on invertebrates resulting from Alternative 2 activities would be nearly identical to those from Alternative 1.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	***Summary of Impacts***
Section 3.5 Habitats	The Navy considered all potential stressors that habitats could be exposed to from the Proposed Action. The following conclusions have been reached for the project alternatives: **<u>No Action Alternative</u>:** • Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various stressors (e.g., military expended materials other than munitions) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities. **<u>Alternative 1 (Preferred Alternative)</u>:** • <u>Explosives</u>: Most of the high-explosive military expended materials would detonate at or near the water surface. The surface area of bottom substrate affected would be a tiny fraction of the total training and testing area available in the Study Area. • <u>Physical Disturbance and Strike</u>: Most seafloor devices would be placed in areas that would result in minor and temporary bottom substrate impacts. Once on the seafloor and over time, military expended materials would be buried by sediment, corroded from exposure to the marine environment, or colonized by benthic organisms. The surface area of bottom substrate affected over the short-term would be a tiny fraction of the total training and testing area available in the Study Area. **<u>Alternative 2</u>:** • <u>Explosives</u>: Explosive activities that could impact habitats would be nearly identical under Alternative 2 as those analyzed under Alternative 1. In-water explosions under Alternative 2 training and testing activities would be limited to local and short term impacts on marine habitat structure in the Study Area. • <u>Physical Disturbance and Strike</u>: Under Alternative 2, potential physical disturbance and strike impacts on habitats associated with training and testing activities would be similar to those discussed under Alternative 1. The surface area of bottom substrate affected over the short-term would be a tiny fraction of the total training and testing area available in the Study Area.
Section 3.6 Fishes	The Navy considered all potential stressors that fishes could be exposed to from the Proposed Action. The following conclusions have been reached for the project alternatives: **<u>No Action Alternative</u>:** • Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. The combined impacts of all stressors for fishes would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities, and no impacts on fish population would occur.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	***Summary of Impacts***
Section 3.6 Fishes (continued)	**<u>Alternative 1 (Preferred Alternative)</u>:** • <u>Acoustics</u>: The use of sonar and other transducers, air guns, pile driving, vessel noise, aircraft noise, and weapons noise could result in impacts on fishes in the Study Area. Some sonars and other transducers, vessel noise, and weapons noise could result in hearing loss, masking, physiological stress, or behavioral reactions. Aircraft noise would not likely result in impacts other than brief, mild behavioral responses in fishes that are close to the surface. Air guns and pile driving have the potential to result in the same effects in addition to mortality or injury. Most impacts, such as masking or behavioral reactions, are expected to be temporary and infrequent as most activities involving acoustic stressors would be at low levels of noise, temporary, localized, and infrequent. More severe impacts such as mortality or injury could lead to permanent or long-term consequences for individuals, but, overall, long-term consequences for fish populations are not expected. • <u>Explosives</u>: The use of explosives could result in impacts on fishes within the Study Area. Sound and energy from explosions is capable of causing mortality, injury, hearing loss, masking, physiological stress, or behavioral responses. The time scale of individual explosions is very limited, and training and testing exercises involving explosions are dispersed in space and time; therefore, repeated exposure of individual fishes are unlikely. Most effects such as hearing loss or behavioral responses are expected to be short-term and localized. More severe impacts such as mortality or injury could lead to permanent or long-term consequences for individuals but, overall, long-term consequences for fish populations are not expected. • <u>Energy</u>: The use of in-water electromagnetic devices may elicit brief behavioral or physiological stress responses only in those exposed fishes with sensitivities to the electromagnetic spectrum. This behavioral impact is expected to be temporary and minor. Similar to regular vessel traffic that is continuously moving and covers only a small spatial area during use, in-water electromagnetic fields would be continuously moving and cover only a small spatial area during use; thus, population-level impacts are unlikely. • <u>Physical Disturbance and Strike</u>: Impacts on fishes from vessel strikes, in-water device strikes, military expended material strikes, and seafloor device strikes are highly unlikely because most fishes are highly mobile and have sensory capabilities that enable the detection and avoidance of vessels, expended materials, or objects in the water column or on the seafloor. The only exceptions are a few large, slow-moving species such as manta rays, ocean sunfish, and whale sharks that occur near the surface in some areas. Long-term consequences from vessel strikes for individuals and fish populations are not expected. • <u>Entanglement</u>: Fishes could be exposed to multiple entanglement stressors associated with Navy training and testing activities. The potential for impacts is dependent on the physical properties of the expended materials and the likelihood that a fish would encounter a potential entanglement stressor and then become entangled in it. Physical characteristics of wires and cables, decelerators/parachutes, and biodegradable polymers, combined with the sparse distribution of these items throughout the Study Area, indicates a very low potential for fishes to encounter and become entangled in them. Because of the low numbers of fishes potentially impacted by entanglement stressors, population-level impacts are unlikely.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	***Summary of Impacts***
Section 3.6 Fishes (continued)	• Ingestion: The likelihood that expended items would cause a potential impact on a given fish species depends on the size and feeding habits of the fish and the rate at which the fish encounters the item and the composition of the item. Military expended materials from munitions present an ingestion risk to fishes that forage in the water column and on the seafloor. Military expended materials other than munitions present an ingestion risk for fishes foraging at or near the surface while these materials are buoyant, and on the seafloor when the materials sink. Because of the low numbers of fishes potentially impacted by ingestion stressors, population-level impacts are unlikely. • Secondary: Effects on sediment or water quality would be minor, temporary, and localized and could have short-term, small-scale secondary effects on fishes; however, there would be no persistent or large-scale effects on the growth, survival, distribution, or populations of fishes. **Alternative 2:** • Acoustics: Potential impacts on fishes would be similar to those discussed under Alternative 1. The only difference in sonar and other transducer use between Alternatives 1 and 2 is that the number of sonar hours used would be greater under Alternative 2. Air guns and pile driving impacts would be the same under Alternative 2. Potential impacts resulting from vessel noise would be similar to those discussed for activities under Alternative 1. Vessel use in the Study Area would increase by a very small amount (about 1 percent). The only difference in weapons noise impacts between Alternatives 1 and 2 is that the number of munitions used would be greater under Alternative 2; however, the types and severity of impacts would not be discernible from those described under Alternative 1. • Explosives: The locations, number of events, and potential effects associated with explosives would be almost identical, with only a slight increase in the number of events compared to Alternative 1. • Energy: The locations, number of events, and potential effects associated with energy stressors would be the same under Alternatives 1 and 2. • Physical Disturbance and Strike: Under Alternative 2, potential physical disturbance and strike impacts on fishes associated with training and testing activities would be similar to those discussed for activities under Alternative 1. There would be a very small increase in vessel and in-water device use in the Study Area. However, the difference would not result in substantive changes to the potential for or types of impacts on fishes. • Entanglement: There would be a small increase in the number of military expended materials associated with Alternative 2 activities. However, the increase is negligible, and the potential impacts from wires and cables, decelerators/parachutes, and biodegradable polymer under Alternative 2 would be similar to that of Alternative 1.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	*Summary of Impacts*
Section 3.6 Fishes (continued)	• Ingestion: Under Alternative 2, the locations and types of military expended materials used would be the same as those of Alternative 1. There would be an increase in the number of some items expended, such as targets, sonobuoys, bathythermograph equipment, and small decelerators/parachutes. This relatively small increase in the total number of items expended would not be expected to result in substantive changes to the type or degree of impacts on fishes. • Secondary: Secondary impacts on fishes under Alternative 2 activities would be nearly identical to those from Alternative 1.
Section 3.7 Marine Mammals	The Navy considered all potential stressors that marine mammals could be exposed to from the Proposed Action. The following conclusions have been reached for the project alternatives: **No Action Alternative:** • Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various stressors would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities. **Alternative 1 (Preferred Alternative):** • Acoustics: Navy training and testing activities have the potential to expose marine mammals to multiple acoustic stressors. Exposures to sound-producing activities presents risks to marine mammals that could include temporary or permanent hearing threshold shift, auditory masking, physiological stress, or behavioral responses. Individual animals would typically only experience a small number of behavioral responses or temporary hearing threshold shifts per year due to exposure to acoustic stressors, and these are very unlikely to lead to any costs or long-term consequences for individuals or populations. • Explosives: Explosions in the water or near the water's surface present a risk to marine mammals located in close proximity to the explosion, because the resulting shock waves can cause injury or result in the death of an animal. If a marine mammal is farther from an explosion, the impulsive, broadband sounds introduced into the marine environment may cause temporary or permanent hearing threshold shift, auditory masking, physiological stress, or behavioral responses. Because most estimated impacts from explosions are behavioral responses or temporary threshold shifts and because the numbers of marine mammals potentially impacted by explosives are small as compared to each species respective abundance, population-level effects are unlikely. • Energy: Navy training and testing activities have the potential to expose marine mammals to multiple energy stressors. The likelihood and magnitude of energy impacts depends on the proximity of marine mammals to energy stressors. Based on the relatively weak strength of the electromagnetic field created by some Navy activities, a marine mammal would have to be in close proximity for there to be any effect. Impacts on marine mammal migrating behaviors and navigational patterns are not anticipated. Statistical probability analyses demonstrate with a high level of certainty that a marine mammal would not be struck by a high energy laser.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	***Summary of Impacts***
Section 3.7 Marine Mammals (continued)	• Energy: (continued) Energy stressors associated with Navy training and testing activities are temporary and localized in nature, and may result in short-term and minor impacts on individual marine mammals, but would not result in long-term impacts on marine mammal populations. • Physical Disturbance and Strike: Marine mammals would be potentially exposed to multiple physical disturbance and strike stressors associated with Navy training and testing activities. The potential for impacts relies heavily on the probability that marine mammals would be in close proximity to a physical disturbance and strike stressor (e.g., a vessel or a non-explosive munition). Historical data on Navy ship strike records demonstrate a low occurrence of interactions with marine mammals over the last 10 years. Since the Navy does not anticipate a change in the level of vessel use compared to the last decade, the potential for striking a marine mammal remains low. Physical disturbance due to vessel movement and in water devices of individual marine mammals may also occur, but any stress response of avoidance behavior would not be severe enough to have long-term fitness consequences for individual marine mammals. The use of in-water devices during Navy activities involves multiple types of vehicles or towed devices traveling on the water surface, through the water column, or along the seafloor, all of which have the potential to physically disturb or strike marine mammals. No recorded or reported instances of marine mammal strikes have resulted from in-water devices; therefore, impacts on individuals or long-term consequences to marine mammal populations are not anticipated. Potential physical disturbance and strike impacts from military expended materials and seafloor devices are determined through statistical probability analyses. Results for each of these physical disturbance and strike stressors suggests a very low potential for marine mammals to be struck by any of these items. Long-term consequences to marine mammal populations from physical disturbance and strike stressors associated with Navy training and testing activities are not anticipated. • Entanglement: Marine mammals could be exposed to multiple entanglement sources associated with Navy training and testing activities. The potential for impacts is dependent on the probability that a marine mammal would encounter a potential entanglement stressor as well as the physical properties of the expended materials and the likelihood that a marine mammal could become entangled in the item. Physical characteristics of wires and cables, decelerators/parachutes, and other materials suggest that it is not likely a marine mammal would become entangled in these items. While it may be possible for a marine mammal to become entangled in wires or cables, the sparse distribution of these items throughout the Study Area indicates a very low potential for encounter. Short-term impacts on individual marine mammals and long-term impacts on marine mammal populations from entanglement stressors associated with Navy training and testing activities are not anticipated.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	***Summary of Impacts***
Section 3.7 Marine Mammals (continued)	• Ingestion: Navy training and testing activities have the potential to expose marine mammals to ingestion impacts from multiple sources. The potential for impacts relies heavily on feeding behaviors of marine mammals that occur in the Study Area, the physical properties of the expended items, the feasibility that a marine mammal could ingest the items, and the likelihood that a marine mammal would encounter an item. Marine mammals that forage along the water surface or within the water column are less likely to encounter ingestion stressors as they sink through the water column to the seafloor. Most expended materials that would remain floating or suspended within the water column are typically too small to pose a risk of intestinal blockage to any marine mammal that encounters it. Bottom-feeding marine mammals, including odontocete species, humpback whales, and pinnipeds, would be more likely to encounter ingestion stressors that have already sunk to the floor. In the unlikely event that a marine mammal encounters and ingests expended material, the individual might be negatively affected if the material becomes lodged in the digestive tract. The likelihood that a marine mammal would ingest a military expended item associated with Navy training and testing activities is considered low. Long-term consequences to marine mammal populations from ingestion stressors associated with Navy training and testing activities are not anticipated. • Secondary: Marine mammals would be exposed to multiple secondary stressors associated with Navy training and testing activities in the Study Area. In-water explosions have the potential to injure or kill prey species that marine mammals feed on; however, impacts would not substantially impact prey availability for marine mammals. Explosion byproducts are not considered as indirect stressors to marine mammals while mixed in marine sediments or water. Marine mammals may encounter unexploded ordnance underwater or within sediments, but ingestion is very unlikely. Explosion byproducts and unexploded munitions would have no lasting or meaningful effect on water quality and would therefore not constitute a secondary indirect stressor for marine mammals. Metals are introduced into the water and sediments from targets, munitions, and other expended materials. Evidence from a number of studies indicate metal contamination is localized and ephemeral and that bioaccumulation resulting from munitions was not observed in the studies specifically designed to look for bioaccumulation. Therefore it is unlikely that impacts on marine mammal prey availability would occur. Several Navy training and testing activities (e.g., Bombing Exercise Air-to-Surface) introduce explosive byproducts into the marine environment that are potentially harmful in concentration; however, rapid dilution would occur and toxic concentrations are unlikely to be encountered. Furthermore, there is no evidence of acute toxicity or chronic accumulation in tissues of chemicals introduced by Navy activities that would alter water quality to an extent that would result in overall habitat degradation for marine mammals. Transmission of marine mammal diseases and parasites are not considered likely from the Navy's trained marine mammals because strict protocols are in place to prevent such impacts on wild populations. Secondary stressors from Navy training and testing activities in the Study Area are not expected to have short-term impacts on individual marine mammals or long-term impacts on marine mammal populations. Secondary stressors may affect main Hawaiian Islands insular false killer whale and Hawaiian monk seal critical habitats.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	***Summary of Impacts***
Section 3.7 Marine Mammals (continued)	**Alternative 2:** • Acoustics: Potential impacts on marine mammals would be similar to those discussed for training activities under Alternative 1. The only difference in sonar and other transducer use between Alternatives 1 and 2 is that the number of sonar hours used would be greater under Alternative 2. Air guns and pile driving impacts would be the same under Alternative 2. Potential impacts resulting from vessel noise would be similar to those discussed for activities under Alternative 1. Vessel use in the Study Area would increase by a very small amount (about 1 percent). The only difference in weapons noise impacts between Alternatives 1 and 2 is that the number of munitions used would be greater under Alternative 2. While the types of expected impacts on any individual marine mammal would remain the same, more animals could be affected. • Explosives: The locations and number of events involving explosives that could impact marine mammals would be similar to Alternative 1. Therefore, potential effects would be similar as described under Alternative 1. • Energy: The locations, number of events, and potential effects associated with energy stressors would be the same under Alternatives 1 and 2. • Physical Disturbance and Strike: Under Alternative 2, potential physical disturbance and strike impacts on marine mammals associated with training and testing activities would be similar to those discussed for activities under Alternative 1. There would be a very small increase in vessel and in-water device use in the Study Area. However, the difference would not result in substantive changes to the potential for or types of impacts on marine mammals. • Entanglement: There would be a small increase in the number of military expended materials associated with Alternative 2 activities. However, the increase is negligible and the potential impacts from wires and cables, decelerators/parachutes, and biodegradable polymer under Alternative 2 would be similar to that of Alternative 1. • Ingestion: Under Alternative 2, the locations and types of military expended materials used would be the same as those of Alternative 1. There would be an increase in the number of some items expended, such as targets, sonobuoys, bathythermograph equipment, and small decelerators/parachutes. This relatively small increase in the total number of items expended would not be expected to result in substantive changes to the type or degree of impacts on marine mammals. • Secondary: Secondary impacts on marine mammals resulting from Alternative 2 activities would be nearly identical to those from Alternative 1.
Section 3.8 Reptiles	The Navy considered all potential stressors that reptiles could be exposed to from the Proposed Action. The following conclusions have been reached for the project alternatives: **No Action Alternative:** • Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various stressors would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	***Summary of Impacts***
Section 3.8 Reptiles (continued)	**<u>Alternative 1 (Preferred Alternative)</u>:** • <u>Acoustics</u>: Navy training and testing activities have the potential to expose reptiles to multiple acoustic stressors, including sonars and other transducers; air guns; pile driving; and vessel, aircraft, and weapons noise. Reptiles could be affected by only a limited portion of acoustic stressors because reptiles have limited hearing abilities. Exposures to sound-producing activities present risks that could range from hearing loss, auditory masking, physiological stress, or changes in behavior; however, no injurious impacts are predicted due to exposure to any acoustic stressor. Because the number of sea turtles potentially impacted by sound-producing activities is small, population-level effects are unlikely. Sea snakes considered in this analysis rarely occur in the Study Area, and few, if any, impacts are anticipated. • <u>Explosives</u>: Explosions in the water or near the water's surface present a risk to reptiles located in close proximity to the explosion because the shock waves produced by explosives can cause injury or result in death; however, no sea turtle mortalities are predicted. If a sea turtle is farther from an explosion, the intense, impulsive, broadband sounds introduced into the marine environment may cause hearing loss, auditory masking, physiological stress, or changes in behavior. Because the number of sea turtles potentially impacted by explosives is small, population-level effects are unlikely. Sea snakes considered in this analysis rarely occur in the Study Area, and few, if any, impacts are anticipated. • <u>Energy</u>: Navy training and testing activities have the potential to expose sea turtles to multiple energy stressors. Based on the relatively weak strength of the electromagnetic field created by Navy activities, impacts on sea turtles migrating behaviors and navigational patterns are not anticipated. Potential impacts from high-energy lasers would only result in sea turtles directly struck by the laser beam. Statistical probability analyses demonstrate with a high level of certainty that no sea turtles would be struck by a high-energy laser. Energy stressors associated with Navy training and testing activities are temporary and localized in nature, and based on patchy distribution of animals, no impacts on individual reptile or reptile populations are anticipated. • <u>Physical Disturbance and Strike</u>: Vessels, in-water devices, and seafloor devices present a risk for collision with sea turtles, particularly in coastal areas where densities are higher. Strike potential by expended materials is statistically small. Because of the low numbers of sea turtles potentially impacted by activities that may cause a physical disturbance and strike, population-level effects are unlikely. Sea snakes considered in this analysis rarely occur in the Study Area, and few, if any, impacts are anticipated. • <u>Entanglement</u>: Sea turtles could be exposed to multiple entanglement stressors associated with Navy training and testing activities. The potential for impacts is dependent on the physical properties of the expended materials and the likelihood that a sea turtle would encounter a potential entanglement stressor and then become entangled in it. Physical characteristics of wires and cables, decelerators/parachutes, and biodegradable polymers combined with the sparse distribution of these items throughout the Study Area indicate a very low potential for sea turtles to encounter and become entangled in them. Long-term impacts on individual sea turtles and sea turtle populations from entanglement stressors associated with Navy training and testing activities are not anticipated. Sea snakes considered in this analysis rarely occur in the Study Area, and few, if any, impacts are anticipated.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	***Summary of Impacts***
Section 3.8 Reptiles (continued)	• Ingestion: Navy training and testing activities have the potential to expose sea turtles to multiple ingestion stressors and associated impacts. The likelihood and magnitude of impacts depends on the physical properties of the military expended items, the feeding behaviors of sea turtles that occur in the Study Area, and the likelihood that a sea turtle would encounter and incidentally ingest the items. Adverse impacts from ingestion of military expended materials would be limited to the unlikely event that a sea turtle would be harmed by ingesting an item that becomes embedded in tissue or is too large to be passed through the digestive system. The likelihood that a sea turtle would encounter and subsequently ingest a military expended item associated with Navy training and testing activities is considered low. Long-term consequences to sea turtle populations from ingestion stressors associated with Navy training and testing activities are not anticipated. Sea snakes considered in this analysis rarely occur in the Study Area, and few, if any, impacts are anticipated. • Secondary: Sea turtles could be exposed to multiple secondary stressors (indirect stressors to habitat or prey) associated with Navy training and testing activities in the Study Area. In-water explosions have the potential to injure or kill prey species that sea turtles feed on within a small area affected by the blast; however, impacts would not substantially impact prey availability for sea turtles. Explosion byproducts and unexploded munitions would have no meaningful effect on water or sediment quality; therefore, they are not considered to be secondary stressors for sea turtles. Metals are introduced into the water and sediments from multiple types of military expended materials. Available research indicates metal contamination is very localized and that bioaccumulation resulting from munitions would not occur. Several Navy training and testing activities introduce chemicals into the marine environment that are potentially harmful in concentration in the water column or in resuspended sediments; however, through rapid dilution, toxic concentrations are unlikely to be encountered by sea turtles. Furthermore, bioconcentration or bioaccumulation of chemicals introduced by Navy activities to levels that would significantly alter water quality and degrade sea turtle habitat has not been documented. Secondary stressors from Navy training and testing activities in the Study Area are not expected to have short-term impacts on individual sea turtles or long-term impacts on sea turtle populations. **Alternative 2:** • Acoustics: Potential impacts on reptiles would be similar to those discussed under Alternative 1. The only difference in sonar and other transducer use between Alternatives 1 and 2 is that the number of sonar hours used would be greater under Alternative 2. Air guns and pile driving impacts would be the same as discussed under Alternative 1. Potential impacts resulting from vessel noise would be similar to those discussed for activities under Alternative 1. Vessel use in the Study Area would increase by a very small amount (about 1 percent). The only difference in weapons noise impacts between Alternatives 1 and 2 is that the number of munitions used would be greater under Alternative 2. While the types of expected impacts on any individual reptile would remain the same, more animals could be affected.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	*Summary of Impacts*
Section 3.8 Reptiles (continued)	• Explosives: The locations and number of events involving explosives that could impact reptiles would be similar to Alternative 1. Therefore, potential effects would be similar as described under Alternative 1. • Energy: The locations, number of events, and potential effects associated with energy stressors would be the same under Alternatives 1 and 2. • Physical Disturbance and Strike: Under Alternative 2, potential physical disturbance and strike impacts on reptiles would be similar to those discussed for activities under Alternative 1. There would be a very small increase in vessel and in-water device use in the Study Area. However, the difference would not result in substantive changes to the potential for or types of impacts on reptiles. • Entanglement: There would be a small increase in the number of military expended materials associated with Alternative 2 activities. However, the increase is negligible, and the potential impacts from wires and cables, decelerators/parachutes, and biodegradable polymer under Alternative 2 would be similar to that of Alternative 1. • Ingestion: Under Alternative 2, the locations and types of military expended materials used would be the same as those of Alternative 1. There would be an increase in the number of some items expended, such as targets, sonobuoys, bathythermograph equipment, and small decelerators/parachutes. This relatively small increase in the total number of items expended would not be expected to result in substantive changes to the type or degree of impacts on reptiles. • Secondary: Secondary impacts on reptiles resulting from Alternative 2 activities would be nearly identical to those from Alternative 1.
Section 3.9 Birds	The Navy considered all potential stressors that birds could be exposed to from the Proposed Action. The following conclusions have been reached for the project alternatives: **No Action Alternative:** • Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various stressors would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities. **Alternative 1 (Preferred Alternative):** • Acoustics: Navy training and testing activities have the potential to expose birds to a variety of acoustic stressors. The exposure to underwater sounds by birds depends on the species and foraging method. Pursuit divers may remain underwater for minutes, increasing the chance of underwater sound exposure. The exposure to in-air sounds by birds depends on the activity (in flight or on the water surface) and the proximity to the sound source. Because birds are less susceptible to both temporary and permanent threshold shifts than mammals, unless very close to an intense sound source, responses by birds to acoustic stressors would likely be limited to short-term behavioral responses.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	***Summary of Impacts***
Section 3.9 Birds (continued)	• Acoustics (continued): Because birds are less susceptible to both temporary and permanent threshold shifts than mammals, responses by birds to acoustic stressors would likely be limited to short-term behavioral responses unless very close to an intense sound source. Some birds may be temporarily displaced and there may be temporary increases in stress levels. Although individual birds may be impacted, population-level impacts are not expected. • Explosives: Navy training and testing activities have the potential to expose birds to explosions in the water, near the water surface, and in the air. Sounds generated by most small underwater explosions are unlikely to disturb birds above the water surface. If a detonation is sufficiently large or is near the water surface, however, birds above the pressure released at the air-water interface could be injured or killed. Detonations in air could injure birds while either in flight or at the water surface; however, detonations in air during anti-air warfare training and testing would typically occur at much higher altitudes where seabirds and migrating birds are less likely to be present. Detonations may attract birds to possible fish kills, which could cause bird mortalities or injuries if there are multiple detonations in a single event. An explosive detonation would likely cause a startle reaction, as the exposure would be brief and any reactions are expected to be short term. Although a few individuals may experience long-term impacts and potential mortality, population-level impacts are not expected. • Energy: The impact of energy stressors on birds is expected to be negligible based on (1) the limited geographic area in which they are used, (2) the rare chance that an individual bird would be exposed to these devices in use, and (3) the tendency of birds to temporarily avoid areas of activity when and where the devices are in use. The impacts of energy stressors would be limited to individual cases where a bird might become temporarily disoriented and change flight direction, or be injured. Although a small number of individuals may be impacted, the impact at the population level would be negligible. • Physical Disturbance and Strike: There is the potential for individual birds to be injured or killed by physical disturbance and strikes during training and testing. However, species or population-level impacts would not occur due to the vast area over which training and testing activities occur, the comparatively small size of birds, and their ability to flee disturbance. • Entanglement: Entanglement stressors have the potential to impact birds. However, the likelihood is low, since certain activities take place in specific locations or depth zones within the Study Area outside the range or foraging abilities of most birds. A small number of individuals may be impacted, but no direct impacts at the population level would be expected. • Ingestion: It is possible that persistent expended materials could be accidentally ingested by birds during foraging. The likelihood of ingestion is low since (1) foraging depths of diving birds is generally restricted to the surface of the water or shallow depths, (2) the material is unlikely to be mistaken for prey, and (3) most of the material remains at or near the sea surface for a short length of time. No population-level effect to any bird species would be anticipated. • Secondary: There would be relatively localized, temporary impacts from water quality (turbidity) which may alter foraging conditions, but no impacts on prey availability.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	***Summary of Impacts***
Section 3.9 Birds (continued)	**<u>Alternative 2</u>:** • <u>Acoustics</u>: Alternative 2 has an increase in sonar use compared to Alternative 1; however, potential impacts from Alternative 2 activities would be similar to those of Alternative 1. While individual birds may be impacted by training or testing activities, population-level impacts are not expected. • <u>Explosives</u>: There would be minor increase in explosives use under Alternative 2 compared to Alternative 1; however, the types of potential impacts and locations of impacts would be the same as those described under Alternative 1. Most impacts on individual birds, if any, are expected to be minor and limited. Although a few individuals may experience long-term impacts and potential mortality, population-level impacts are not expected, and explosives will not have a significant adverse effect on populations of migratory bird species. • <u>Energy</u>: The number and distribution of training and testing activities using in-water electromagnetic devices under Alternative 2 would be the same as under Alternative 1; therefore, the impacts would be the same as for Alternative 1. Likewise, the number and distribution of training and testing activities using in-air electromagnetic devices under Alternative 2 would differ slightly from Alternative 1; however, the difference is inconsequential and the impacts would be essentially the same as for Alternative 1. The use of high-energy lasers under Alternative 2 would be the same as under Alternative 1; therefore, impacts would be the same. • <u>Physical Disturbance and Strike</u>: Under Alternative 2, potential impacts on birds resulting from training and testing activities would be slightly greater but would still be inconsequential due to the relatively small number of individuals affected and the lack of population-level effects. • <u>Entanglement</u>: Under Alternative 2, increases in sonobuoy component release and the number of decelerators/parachutes that would be expended would proportionally increase the possibility of entanglement relative to Alternative 1. However, the likelihood of injury or mortality is still considered negligible, and the potential impacts from Alternative 2 activities would be the same as for Alternative 1. • <u>Ingestion</u>: Activities under Alternative 2 would generate the same types of ingestible materials generated under Alternative 1. The distribution and abundance of ingestion stressors would be the same as under Alternative 1. Therefore, the implementation of Alternative 2 would have similar impacts on those of training and testing activities under Alternative 1. • <u>Secondary</u>: Potential impacts from secondary stressors under Alternative 2 would be the same as Alternative 1.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	***Summary of Impacts***
Section 3.10 Cultural Resources	The Navy considered all potential stressors that cultural resources could be exposed to from the Proposed Action. The following conclusions have been reached for the project alternatives: **No Action Alternative:** • Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various stressors would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities. **Alternative 1 (Preferred Alternative):** • Explosive: Explosive stressors resulting from underwater explosions creating shock waves and cratering of the seafloor would not result in adverse effects to known submerged cultural resources. Therefore, no submerged cultural resources are expected to be impacted. • Physical Disturbance and Strike: Physical disturbance and strike stressors resulting from in-water devices, military expended materials, seafloor devices, pile driving, and vibration from sonic booms during training and testing activities would not result in adverse effects to known submerged cultural resources. Therefore, no submerged cultural resources are expected to be affected. **Alternative 2:** • Explosives: The locations and number of events involving explosives that could impact cultural resources would be similar to Alternative 1. Therefore, potential effects would be similar as described under Alternative 1. • Physical Disturbance and Strike: Under Alternative 2, potential impacts on known submerged cultural resources resulting from activities would be slightly greater but would still be inconsequential.
Section 3.11 Socioeconomic Resources	The Navy considered all potential stressors that socioeconomic resources could be exposed to from the Proposed Action. The following conclusions have been reached for the project alternatives: **No Action Alternative:** • Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various stressors would not be introduced into the marine environment. Therefore, training and testing activities would not limit accessibility to air and sea space (although other Navy activities would still use established ranges, warning areas, and danger zones), generate airborne noise, or cause physical disturbances and strikes. Ceasing the proposed training and testing activities may reduce the number and types of jobs available in locations where the Navy is a vital or even the primary economic driver sustaining local communities. The secondary effects from reducing personnel who support Navy training and testing activities could include a decline in local business and a decrease in the need for infrastructure, such as schools. If jobs are relocated, a smaller population may no longer be able to sustain the local economy that developed to support the larger population.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	***Summary of Impacts***
Section 3.11 Socioeconomic Resources (continued)	**Alternative 1 (Preferred Alternative):** • Accessibility: Limits on accessibility to marine areas used by the public (e.g., fishing areas) in Navy training and testing areas would be temporary and of short duration (hours). Restrictions would be lifted, and conditions would return to normal upon completion of training and testing activities. Minimal impacts on commercial and recreational fishing and tourism may occur; however, limits on accessibility would not result in a direct loss of income, revenue or employment, resource availability, or quality of experience. No impacts on commercial transportation and shipping, and subsistence fishing are anticipated. • Airborne Acoustics: Because the majority of Navy training and testing activities are conducted far from where tourism and recreational activities are concentrated, the impact of airborne noise would be negligible. The public may intermittently hear noise from transiting ships or aircraft overflights if they are in the general vicinity of a training or testing activity, but these occurrences would be infrequent. The infrequent exposure to airborne noise would not result in a direct loss of income, revenue or employment, resource availability, or quality of experience. No impacts on commercial transportation and shipping, and subsistence fishing are anticipated. • Physical Disturbance and Strike: Because the majority of Navy training and testing activities are conducted farther from shore than where most recreational activities are concentrated, the potential for a physical disturbance or strike affecting recreational fishing and tourism in offshore areas is negligible. In locations where Navy training or testing occurs in nearshore areas (e.g., San Diego Bay), the Navy coordinates with civilian organizations to assure safe and unimpeded access and use of those areas. Based on the Navy's standard operating procedures and the large expanse of the testing and training ranges, the likelihood of a physical disturbance or strike disrupting commercial transportation and shipping, commercial and recreational fishing, subsistence fishing, and tourism would be negligible. Therefore, direct loss of income, revenue or employment, resource availability, or quality of experience would not be expected. **Alternative 2:** • Accessibility: Limits on accessibility to marine areas used by the public could increase under Alternative 2 due to an increase in some training and testing activities. However, the difference in potential impacts on access would be undetectable. • Airborne Acoustics: The number of activities that could generate airborne noise detectable by the public would increase under Alternative 2. However, the difference in acoustic impacts would be inconsequential. • Physical Disturbance and Strike: Under Alternative 2, potential physical disturbance and strike impacts associated with training and testing activities would be similar to those discussed under Alternative 1. There would be a very small increase in vessel and in-water device use in the Study Area. However, the difference would not result in substantive changes to the potential for or types of impacts.

Table ES-1: Summary of Environmental Impacts for the No Action Alternative, Alternative 1, and Alternative 2 (continued)

Resource Category	*Summary of Impacts*
Section 3.12 Public Health and Safety	The Navy considered all potential stressors that public health and safety could be exposed to from the Proposed Action. The following conclusions have been reached for the project alternatives: **No Action Alternative:** • Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. There would be no appreciable change in potential impacts on public health and safety under the No Action Alternative, as these activities (currently or as proposed) would be unlikely to affect public health and safety. However, diminished military readiness under the No Action Alternative would adversely affect public health and safety. **Alternative 1 (Preferred Alternative):** • In-Water Energy: Because of the Navy's standard operating procedures, impacts on public health and safety would be unlikely. • In-Air Energy: Because of the Navy's standard operating procedures, impacts on public health and safety would be unlikely. • Physical Interactions: Because of the Navy's standard operating procedures, impacts on public health and safety would be unlikely. • Secondary Stressors (sediments and water quality): Impacts on public health and safety would be unlikely. **Alternative 2:** • In-Water Energy: The locations, number of events, and potential effects associated with energy stressors would be the same under Alternatives 1 and 2. • In-Air Energy: The locations, number of events, and potential effects associated with energy stressors would be the same under Alternatives 1 and 2. • Physical Interactions: Because of the Navy's standard operating procedures, in spite of increased levels of activity under Alternative 2, impacts on public health and safety would remain unlikely. • Secondary Stressors (sediments and water quality): Potential impacts from secondary stressors under Alternative 2 would be the same as Alternative 1.

ES.6 Cumulative Impacts

Cumulative impacts were analyzed for each resource addressed in Chapter 3 (Affected Environment and Environmental Consequences) for the No Action Alternative, Alternative 1 (Preferred Alternative), and Alternative 2 in combination with past, present, and reasonably foreseeable future actions. Analysis was not separated by alternative because the data available for the cumulative effects analysis was mostly qualitative in nature and, from a landscape-level perspective, these qualitative impacts are expected to be generally similar.

In accordance with Council on Environmental Quality guidance, the cumulative impacts analysis focused on impacts that are "truly meaningful." The level of analysis for each resource was commensurate with the intensity of the impacts identified in Chapter 3 (Affected Environment and Environmental Consequences).

ES.6.1 Projects and Other Activities Analyzed for Cumulative Impacts Analysis

Cumulative impacts analysis includes consideration of past, present, and reasonably foreseeable future actions. For past actions, the cumulative impacts analysis only considers those actions or activities that have had ongoing impacts that may be additive to impacts of the Proposed Action. Likewise, present and reasonably foreseeable future actions selected for inclusion in the analysis are those that may have effects additive to the effects of the Proposed Action as experienced by specific environmental receptors.

The cumulative impacts analysis is not bounded by a specific future timeframe. The Proposed Action includes general types of activities addressed by this EIS/OEIS that are expected to continue indefinitely, and the associated impacts could occur indefinitely. Likewise, some reasonably foreseeable future actions and other environmental considerations addressed in the cumulative impacts analysis are expected to continue indefinitely (e.g., oil and gas production, maritime traffic, commercial fishing). While Navy training and testing requirements change over time in response to world events, it should be recognized that available information, uncertainties, and other practical constraints limit the ability to analyze cumulative impacts for the reasonably foreseeable future.

ES.6.2 Resource-Specific Cumulative Impact Conclusions

As a result of the analysis conducted in Chapter 4 (Cumulative Impacts), the following conclusions were determined for each analyzed resource.

ES.6.2.1 Air Quality

Activities in the Study Area that contribute to emissions of criteria air pollutants include other vessel traffic and oil and gas production activities, as well as from landside power-generating stations, petroleum refining, agriculture, other industry, vehicle traffic, and volcanoes (Hawaii).

Sources of emissions from the proposed alternatives would include Navy vessels, aircraft, and, to a lesser extent, munitions training and testing activities conducted throughout the Study Area. The Proposed Action alternatives would result in localized and temporarily elevated emissions, but overall, criteria pollutant emissions in nonattainment or maintenance areas would not exceed *de minimis* thresholds. Hazardous air pollutant emissions are anticipated to be so minute that they were dismissed as a stressor of impact.

Although it is anticipated that emissions resulting from the Proposed Action would quickly disperse in the ocean environment and largely degrade rather than concentrate due to meteorological and air chemistry processes, under various scenarios these emissions could intermix with emissions from other vessel traffic in the open ocean. The incremental additive impacts from these combined emissions would be minor, localized, intermittent, and unlikely to contribute to future degradation of the ocean atmosphere in a way that would harm ocean ecosystems or nearshore communities. Thus, it is anticipated that the incremental contribution of the Proposed Action, when added to the impacts of all other past, present and reasonably foreseeable future actions would not result in measurable additional impacts on air quality in the Study Area or beyond.

ES.6.2.2 Sediments and Water Quality

It is possible that Navy stressors would combine with non-Navy stressors, particularly in nearshore areas and bays, such as Pearl Harbor and San Diego Bay, to exacerbate already impacted sediments and water quality. Although impacts may temporarily intermingle with other inputs in areas with degraded existing conditions, most of the Navy impacts on water quality and turbidity are expected to be negligible, isolated, and short term, with disturbed sediments and particulate matter quickly dispersing within the water column or settling to the seafloor and turbidity conditions returning to background levels. The Proposed Action could incrementally contribute persistent metal and plastic materials primarily to the offshore ocean ecosystems. However, the relatively minute concentrations of Navy stressors are not likely to combine with other past, present, or reasonably foreseeable activities in a way that would cumulatively threaten the water and sediment quality within the Study Area.

ES.6.2.3 Vegetation

The effects of other past, present, and reasonably foreseeable actions on vegetation occur primarily in the coastal and inland waters and are associated with coastal development, maritime commerce/dredging, and the discharge of sediment and other pollutants. The Proposed Action is not expected to substantially contribute to losses of vegetation that would interfere with recovery in these regions. The incremental contribution of the Proposed Action would be insignificant as most of the proposed activities would occur in areas where seagrasses and other attached marine vegetation do not grow; impacts would be localized; recovery would occur quickly; and the Proposed Action would not compound impacts that have been historically significant to marine vegetation (loss of habitat due to development; nutrient loading; shading; turbidity; or changes in salinity, pH, or water temperature). Although vegetation is impacted by stressors throughout the Study Area, the Proposed Action is not likely to incrementally contribute to population- or ecosystem-level changes in the resource, and it is anticipated that the incremental contribution of the Proposed Action, when added to the impacts of all other past, present and reasonably foreseeable future actions, would not result in measurable additional impacts on vegetation in the Study Area or beyond.

ES.6.2.4 Invertebrates

The analysis presented in Section 3.4 (Invertebrates), indicates that marine invertebrates could be affected by acoustic stressors, electromagnetic stressors, physical disturbance or strike stressors, entanglement, and ingestion. Potential impacts include short-term behavioral and physiological responses. Some stressors could also result in injury or mortality to a relatively small number of individuals.

Some direct impacts on invertebrates are expected, and the impacts of the Proposed Action could be cumulative with other actions that cause disturbance and mortality of marine invertebrates. However, it is anticipated that the incremental contribution of the proposed alternatives would be insignificant.

Although marine invertebrates are impacted by other stressors in the ocean environment, the Proposed Action is not likely to incrementally contribute to population-level stress and decline of the resource. As impacts would be isolated, localized, and not likely to overlap with other relevant stressors, it is anticipated that the incremental contribution of the Proposed Action, when added to the impacts of all other past, present and reasonably foreseeable future actions, would not result in measurable additional impacts on invertebrates in the Study Area or beyond.

ES.6.2.5 Habitats

Although it is anticipated that damage to abiotic soft bottom habitat resulting from the Proposed Action would be limited and would recover, many other activities in the ocean are also impacting ocean bottom habitat. However, it is not likely that past, present, and future impacts would overlap the Proposed Action activities in place or time before the craters or other impressions in soft bottom substrate fill in. Likewise, hard bottom habitat would be avoided to the greatest extent possible. Based on the analysis and the reasons summarized above, it is anticipated that the incremental contribution of the Proposed Action, when added to the impacts of all other past, present and reasonably foreseeable future actions, would not result in measurable additional impacts on habitats, including National Marine Sanctuaries, in the Study Area or beyond.

ES.6.2.6 Fishes

The aggregate impacts of past, present, and other reasonably foreseeable future actions contributing multiple water quality, noise, and physical risks to fishes would likely continue to have significant effects on individual fishes and fish populations. However, Navy training and testing activities are generally isolated from other activities in space and time and the majority of the proposed training and testing activities occur over a small spatial scale relative to the entire Study Area, have few participants, and are of a short duration. Although it is possible that the Proposed Action could contribute incremental stressors to a small number of individuals, which would further compound effects on a given individual already experiencing stress, it is not anticipated that the Proposed Action has the potential to put additional stress on entire populations, some of which may already be in significant decline or in the midst of stabilization and recovery. Therefore, it is anticipated that the incremental contribution of the Proposed Action, when added to the impacts of all other past, present and reasonably foreseeable future actions, would not result in measurable additional significant impacts on fishes in the Study Area or beyond.

ES.6.2.7 Marine Mammals

The aggregate impacts of past, present, and other reasonably foreseeable future actions continue to have significant impacts on some marine mammal species in the Study Area. The Proposed Action could contribute incremental stressors to individuals, which would both further compound effects on a given individual already experiencing stress and, in turn, have the potential to further stress populations, some of which may already be in significant decline or in the midst of stabilization and recovery. However, with the implementation of standard operating procedures reducing the likelihood of overlap in time and space with other stressors and the implementation of mitigation measures reducing the likelihood of impacts, the incremental stressors anticipated from the Proposed Action are not anticipated to be significant.

ES.6.2.8 Reptiles

The aggregate impacts of past, present, and other reasonably foreseeable future actions continue to have significant impacts on all reptile species in the Study Area. The Proposed Action could contribute incremental stressors to individuals, which would both further compound effects on a given individual already experiencing stress and in turn has the potential to further stress populations in significant decline or recovery efforts thereof. However, with the implementation of standard operating procedures reducing the likelihood of overlap in time and space with other stressors and the implementation of mitigation measures reducing the likelihood of impacts, the incremental stressors anticipated from the Proposed Action are not anticipated to be significant.

ES.6.2.9 Birds

The analysis indicates that birds could be affected by acoustic stressors, explosives stressors, energy stressors, physical disturbance and strikes, and ingestion. Potential responses would include a startle response, which includes short-term behavioral (i.e., movement) and physiological components (i.e., increased heart rate). Recovery from the impacts of most stressor exposures would occur quickly, and impacts would be localized. Some stressors, including underwater explosions, physical strikes, and ingestion of military expended materials, could result in mortality. However, the number of individual birds affected would be low, and no population-level impacts are expected.

Although other past, present, and reasonably foreseeable actions individually and collectively cause widespread disturbance and mortality of bird populations across the ocean landscape, the Proposed Action is not expected to substantially contribute to their diminishing abundance, induce widespread behavioral or physiological stress, or interfere with recovery from other stressors. It is anticipated that the incremental contribution of the Proposed Action, when added to the impacts of all other past, present and reasonably foreseeable future actions, would not result in measurable additional impacts on birds in the Study Area or beyond.

ES.6.2.10 Cultural Resources

As discussed in Section 3.10 (Cultural Resources), stressors, including explosive and physical disturbance and strike stressors, associated with the Proposed Action would not affect submerged prehistoric sites and submerged historic resources in accordance with Section 106 of the National Historic Preservation Act because mitigation measures have been implemented to protect and avoid these resources (Chapter 5, Mitigation). Furthermore, programmatic agreements between the Navy and State Historic Preservation Offices exist to address the protection and management of cultural resources. The Proposed Action is not expected to result in impacts on cultural resources in the Study Area and likewise would not contribute incrementally to cumulative impacts on cultural resources. Therefore, further analysis of cumulative impacts on cultural resources is not warranted.

ES.6.2.11 Socioeconomic Resources

The analysis indicates that the Proposed Action is not expected to result in long-term impacts on socioeconomic resources in the Study Area, including energy production and distribution, mineral extraction, commercial transportation and shipping, commercial and recreational fishing, aquaculture, and tourism. Minimal temporary and short-term (hours) impacts may occur from limits on accessibility to marine areas used by the public, and the public may intermittently hear noise from transiting ships or aircraft overflights if they are in the general vicinity of a training or testing activity. But these occurrences would be infrequent, and other than transiting, most Navy training and testing occurs farther from shore than most recreational and tourism activities. Temporary limitations on accessibility to marine areas and the infrequent exposure to airborne noise would not result in a direct loss of income, revenue or employment, resource availability, or quality of experience. No impacts on sources for energy production and distribution, mineral extraction, and aquaculture are anticipated. Short-term impacts, should they occur, would not contribute incrementally to cumulative socioeconomic impacts.

ES.6.2.12 Public Health and Safety

All Proposed Actions would be accomplished by technically qualified personnel and would be conducted in accordance with applicable Navy, state, and federal safety standards and requirements. The analysis presented indicates that the Proposed Action is not expected to result in impacts on public health and safety and thus would not contribute incrementally to or combine with other impacts on health and safety within the Study Area.

ES.6.3 Summary of Cumulative Impacts

The Action Alternatives would contribute incremental effects on the ocean ecosystem, which is already experiencing and absorbing a multitude of stressors to a variety of receptors. In general, it is not anticipated that the implementation of the Proposed Action would have meaningful contribution to the ongoing stress or cause significant collapse of any particular marine resource, but it would further cause minute impacts on resources that are already experiencing various degrees of interference and degradation. It is intended that the mitigation measures described in Chapter 5 (Mitigation) will further reduce the potential impacts of the Proposed Action in such a way that they are avoided to the maximum extent practicable and to ensure that impacts do not become cumulatively significant to any marine resource.

Marine mammals and sea turtles are the primary resources of concern for cumulative impacts analysis, but the Proposed Action is not anticipated to meaningfully contribute to the decline of these populations or affect the stabilization and recovery thereof. The Navy proposes to implement standard operating procedures that reduce the likelihood of overlap of Navy stressors in time and space with non-Navy stressors, and mitigation measures as described in Chapter 5 (Mitigation) reduce the risk of direct impacts of the Proposed Action on individual animals.

The aggregate impacts of past, present, and other reasonably foreseeable future actions have resulted in significant impacts on some marine mammal and all sea turtle species in the Study Area; however, the decline of these species is chiefly attributable to other stressors in the environment, including the synergistic effect of bycatch, entanglement, vessel traffic, ocean pollution, and coastal zone development. The analysis presented in Chapter 4 (Cumulative Impacts) and Chapter 3 (Affected Environment and Environmental Consequences) indicates that the incremental contribution of the Proposed Action to cumulative impacts on air quality, sediments and water quality, vegetation, invertebrates, marine habitats, fishes, birds, cultural and socioeconomic resources, and public health and safety would not significantly contribute to cumulative stress on those resources.

ES.7 Mitigation

The Navy has been mitigating impacts from military readiness activities on environmental and cultural resources throughout areas where it trains and tests for more than two decades. In coordination with the appropriate regulatory agencies, the Navy developed mitigation measures for the Proposed Action that will effectively avoid or reduce potential impacts and that are practical to implement. Chapter 5 (Mitigation) presents full descriptions of mitigation measures the Navy will implement, discussions of how the Navy developed and assessed each measure, and discussions of measures considered but eliminated.

Mitigation measures that the Navy will implement under the Proposed Action are organized into two categories: procedural mitigation measures and mitigation areas. The Navy will implement procedural mitigation whenever and wherever training or testing activities involving applicable acoustic, explosive, and physical disturbance and strike stressors occur within the Study Area. Procedural mitigation generally involves: (1) the use of one or more trained Lookouts to observe for specific biological resources (e.g., marine mammals, sea turtles) within a mitigation zone (i.e., area around a stressor), (2) requirements for Lookouts to immediately communicate sightings of specific biological resources to the appropriate watch station for information dissemination, and (3) requirements for the watch station to implement mitigation until certain conditions have been met. Table ES-2 contains a brief summary of the mitigation zones and other procedural mitigation measures that the Navy will implement under the Proposed Action. Additional information on procedural mitigation measures is presented in Section 5.3 (Procedural Mitigation to be Implemented).

Table ES-2: Summary of Mitigation to be Implemented

Stressor or Activity	***Mitigation Zone Sizes and Other Requirements***	***Protection Focus***
Environmental Awareness and Education	• Afloat Environmental Compliance Training program for applicable personnel	Marine mammals, Sea turtles
Active Sonar	Depending on sonar source: • 1,000 yd. power down, 500 yd. power down, and 200 yd. shut down • 200 yd. shut down	Marine mammals, Sea turtles
Air Guns	• 150 yd.	Marine mammals, Sea turtles
Pile Driving	• 100 yd.	Marine mammals, Sea turtles
Weapons Firing Noise	• 30° on either side of the firing line out to 70 yd.	Marine mammals, Sea turtles
Explosive Sonobuoys	• 600 yd.	Marine mammals, Sea turtles
Explosive Torpedoes	• 2,100 yd.	Marine mammals, Sea turtles
Explosive Medium-Caliber and Large-Caliber Projectiles	• 1,000 yd. (large-caliber projectiles) • 600 yd. (medium-caliber projectiles during surface-to-surface activities) • 200 yd. (medium-caliber projectiles during air-to-surface activities)	Marine mammals, Sea turtles
Explosive Missiles and Rockets	• 2,000 yd. (21–500 lb. net explosive weight) • 900 yd. (0.6–20 lb. net explosive weight)	Marine mammals, Sea turtles
Explosive Bombs	• 2,500 yd.	Marine mammals, Sea turtles
Sinking Exercises	• 2.5 NM	Marine mammals, Sea turtles
Explosive Mine Countermeasure and Neutralization Activities	• 2,100 yd. (6–650 lb. net explosive weight) • 600 yd. (0.1–5 lb. net explosive weight)	Marine mammals, Sea turtles, Birds

Table ES-2: Summary of Mitigation to be Implemented (Continued)

Stressor or Activity	*Mitigation Zone Sizes and Other Requirements*	*Protection Focus*
Explosive Mine Neutralization Activities Involving Navy Divers	• 1,000 yd. (21–60 lb. net explosive weight for positive control charges and charges using time-delay fuses) • 500 yd. (0.1–20 lb. net explosive weight for positive control charges)	Marine mammals, Sea turtles, Birds, Fish (scalloped hammerhead sharks)
Underwater Demolition Multiple Charge – Mat Weave and Obstacle Loading	• 700 yd.	Marine mammals, Sea turtles
Maritime Security Operations – Anti-Swimmer Grenades	• 200 yd.	Marine mammals, Sea turtles
Vessel Movement	• 500 yd. (whales) • 200 yd. (other marine mammals) • Vicinity (sea turtles)	Marine mammals, Sea turtles
Towed In-Water Devices	• 250 yd. (marine mammals) • Vicinity (sea turtles)	Marine mammals, Sea turtles
Small-, Medium-, and Large-Caliber Non-Explosive Practice Munitions	• 200 yd.	Marine mammals, Sea turtles
Non-Explosive Missiles and Rockets	• 900 yd.	Marine mammals, Sea turtles
Non-Explosive Bombs and Mine Shapes	• 1,000 yd.	Marine mammals, Sea turtles

Mitigation areas are geographic locations within the Study Area where the Navy will implement mitigation measures to: (1) avoid or reduce impacts on biological or cultural resources that are not observable by Lookouts from the water's surface (i.e., resources for which procedural mitigation cannot be implemented); (2) in combination with procedural mitigation, to effect the least practicable adverse impact on marine mammal species or stocks and their habitat; or (3) in combination with procedural mitigation, ensure that the Proposed Action does not jeopardize the continued existence of endangered or threatened species, or result in destruction or adverse modification of critical habitat. Table ES-3 contains a summary of the mitigation areas that the Navy will implement under the Proposed Action. Additional information on mitigation areas is presented in Section 5.4 (Mitigation Areas to be Implemented) and Appendix K (Geographic Mitigation Assessment). Appendix K (Geographic Mitigation Assessment) presents a full biological assessment and operational analysis of the mitigation areas that the Navy considered for marine mammals.

Table ES-3: Summary of Mitigation to be Implemented Within Mitigation Areas

Summary of Mitigation Area Requirements
Mitigation Areas for Shallow-water Coral Reefs and Precious Coral Beds (year-round)
• The Navy will not conduct precision anchoring (except in designated anchorages); explosive or non-explosive mine countermeasure and neutralization activities; explosive or non-explosive mine neutralization activities involving Navy divers; explosive or non-explosive small-, medium-, and large-caliber gunnery activities using a surface target; explosive or non-explosive missile and rocket activities using a surface target; and explosive or non-explosive bombing or mine-laying activities (except in designated locations). • The Navy will not place mine shapes, anchors, or mooring devices on the seafloor (except in designated locations).
Mitigation Areas for Live Hard Bottom, Artificial Reefs, and Shipwrecks (year-round)
• The Navy will not conduct precision anchoring (except in designated anchorages), explosive mine countermeasure and neutralization activities (except in designated locations), or explosive mine neutralization activities involving Navy divers (except in designated locations). • The Navy will not place mine shapes, anchors, or mooring devices on the seafloor (except in designated locations).
Hawaii Island Mitigation Area (year-round)
• The Navy will not conduct more than 300 hours of MF1 surface ship hull-mounted mid-frequency active sonar or 20 hours of MF4 dipping sonar, or use explosives that could potentially result in takes of marine mammals during training and testing.[1]
4-Islands Region Mitigation Area (November 15 – April 15 for active sonar; year-round for explosives)
• The Navy will not use MF1 surface ship hull-mounted mid-frequency active sonar or explosives that could potentially result in takes of marine mammals during training and testing.[1]
Humpback Whale Special Reporting Areas (December 15 – April 15)
• The Navy will report the total hours of surface ship hull-mounted mid-frequency active sonar used in in the special reporting areas in its annual training and testing activity reports submitted to NMFS.
San Diego Arc, San Nicolas Island, and Santa Monica/Long Beach Mitigation Areas (June 1 – October 31)
• The Navy will not conduct more than a total of 200 hours of MF1 surface ship hull-mounted mid-frequency active sonar in the combined areas, excluding normal maintenance and systems checks, during training and testing.[1] • Within the San Diego Arc Mitigation Area, the Navy will not use explosives that could potentially result in the take of marine mammals during large-caliber gunnery, torpedo, bombing, and missile (including 2.75” rockets) activities during training and testing.[1] • Within the San Nicolas Island Mitigation Area, the Navy will not use explosives that could potentially result in the take of marine mammals during mine warfare, large-caliber gunnery, torpedo, bombing, and missile (including 2.75” rockets) activities during training.[1] • Within the Santa Monica/Long Beach Mitigation Area, the Navy will not use explosives that could potentially result in the take of marine mammals during mine warfare, large-caliber gunnery, torpedo, bombing, and missile (including 2.75” rockets) activities during training and testing.[1]
Santa Barbara Island Mitigation Area (year-round)
• The Navy will not use MF1 surface ship hull-mounted mid-frequency active sonar during training and testing, or explosives that could potentially result in the take of marine mammals during medium-caliber or large-caliber gunnery, torpedo, bombing, and missile (including 2.75” rockets) activities during training.[1]
Awareness Notification Message Areas (seasonal according to species)
• The Navy will issue awareness notification messages to alert ships and aircraft to the possible presence of humpback whales (November–April), blue whales (June–October), gray whales (November–March), or fin whales (November–May).

[1] If naval units need to conduct more than the specified amount of training or testing, they will obtain permission from the appropriate designated Command authority prior to commencement of the activity. The Navy will provide NMFS with advance notification and include the information in its annual activity reports submitted to NMFS.

ES.8 Other Considerations

ES.8.1 Consistency with Other Federal, State, and Local Regulations, and Executive Orders

Based on an evaluation of consistency with statutory obligations, the Navy's proposed training and testing activities would not conflict with the objectives or requirements of federal, state, regional, or local plans, policies, or legal requirements. The Navy consulted with regulatory agencies as appropriate during the NEPA process and prior to implementation of the Proposed Action to ensure all legal requirements are met.

ES.8.2 Relationship Between Short-term Use of the Environment and Maintenance and Enhancement of Long-term Productivity

In accordance with NEPA, this EIS/OEIS provides an analysis of the relationship between a project's short-term impacts on the environment and the effects that these impacts may have on the maintenance and enhancement of the long-term productivity of the affected environment. The Proposed Action may result in both short- and long-term environmental effects. However, the Proposed Action would not be expected to result in any impacts that would reduce environmental productivity, permanently narrow the range of beneficial uses of the environment, or pose long-term risks to health, safety, or the general welfare of the public.

ES.8.3 Irreversible or Irretrievable Commitment of Resources

For both Alternative 1 and Alternative 2, most resource commitments are neither irreversible nor irretrievable. Most impacts are short term and temporary or, if long lasting, are negligible. No habitat associated with threatened or endangered species would be lost as result of implementation of the Proposed Action. Since there would be no building or facility construction, the consumption of materials typically associated with such construction (e.g., concrete, metal, sand, fuel) would not occur. Energy typically associated with construction activities would not be expended and irreversibly lost.

Implementation of the Proposed Action would require fuels used by aircraft and vessels. Since fixed- and rotary-wing flight and ship activities could increase, relative total fuel use could increase. Therefore, if total fuel consumption increased, this nonrenewable resource would be considered irretrievably lost.

ES.8.4 Energy Requirements and Conservation Potential of Alternatives and Efficiency Initiatives

Resources that will be permanently and continually consumed by project implementation include water, electricity, natural gas, and fossil fuels; however, the amount and rate of consumption of these resources would not result in significant environmental impacts or the unnecessary, inefficient, or wasteful use of resources. Prevention of the introduction of potential contaminants is an important component of standard procedures followed by the Navy. To the extent practicable, considerations in the prevention of introduction of potential contaminants are included.

Sustainable range management practices are in place that protect and conserve natural and cultural resources and preserve access to training areas for current and future training requirements while addressing potential encroachments that threaten to impact range and training area capabilities.

ES.9 Public Involvement

The first step in the NEPA process for an EIS is to prepare a Notice of Intent to develop an EIS. The Navy published a Notice of Intent for this EIS/OEIS in the *Federal Register* and several newspapers on November 12, 2015. In addition, Notice of Intent/Notice of Scoping Meeting Letters were distributed to federal, state, and local elected officials and government agencies. The Notice of Intent provided an overview of the Proposed Action and the scope of the EIS, and initiated the scoping process.

ES.9.1 Scoping Process

Scoping is an early and open process for developing the "scope" of issues to be addressed in an EIS and for identifying significant issues related to a proposed action. During scoping, the public helps define and prioritize issues through public meetings and written comments.

The Navy made significant efforts to notify the public to ensure maximum public participation during the scoping process. Notice of Intent and Notice of Scoping Meeting letters were distributed to 661 federally recognized tribes; state-elected officials; and federal, regional, and state agencies. Postcards were mailed to 1,051 recipients on the project mailing list, including individuals, nonprofit organizations, and for-profit organizations. The postcards included the dates, locations, and times for the scoping meetings, as well as the website address for more information. Advertisements, which included a description of the Proposed Action, the address of the project website, the duration of the comment period, and information on how to provide comments, were placed in five newspapers for three days each. Press releases to announce the scoping meetings, describe the Proposed Action, provide the address of the project website, duration of the comment period, and information on the public meetings were distributed to media. The press releases also provided information on the availability of the Navy Environmental Media Officer to meet with the media in advance of the meetings.

Three scoping meetings were held on December 1, 3, and 5, 2015, in the cities of San Diego, CA; Lihue, HI; and Honolulu, HI, respectively. At each scoping meeting, staffers at the welcome station greeted guests and encouraged them to sign in to be added to the project mailing list to receive future notifications. The meetings were held in an open house format, presenting informational posters and written information, with Navy staff and project experts available to answer participants' questions. Additionally, a digital voice recorder was available to record participants' oral comments. The interaction during the information sessions was productive and helpful to the Navy.

ES.9.2 Scoping Comments

Scoping participants submitted comments in four ways:

- Oral statements at the public meetings (as recorded by the tape recorder)
- Written comments at the public meetings
- Written letters (received any time during the public comment period)
- Comments submitted directly on the project website (received any time during the public comment period)

The Navy received oral, written, and electronic comments from federal agencies, state agencies, nongovernmental organizations, individuals, and community groups. A total of 534 website comments were submitted using the electronic comment form on the project website. A total of 24 written comments were also mailed or submitted at the public scoping meetings. Additionally, the Navy received a form letter comment with 73,529 signatures. The comments requested the Navy to analyze environmental issues from physical and biological resources, such as sonar impacts on marine mammals, and on human resources, such as public health and safety. A sampling of some of the specific concerns includes:

- A true No Action Alternative analysis
- Time-area management and mitigation areas
- Cumulative impacts analysis
- Water quality and hazardous materials
- Air quality and air traffic patterns
- Human health and socioeconomic impacts
- Use of simulation
- Lookout effectiveness
- Impacts of training and testing on marine mammals
- Impacts to focal species and essential fish habitat

ES.9.3 Draft EIS/OEIS and Public Comments

The HSTT Draft EIS/OEIS was released for public review and comment October 17, 2017, through December 12, 2017. The Navy made the following significant efforts to facilitate maximum public participation during the Draft EIS/OEIS public review and comment period:

- Notification letters were sent to federal agencies, state agencies, and some non-governmental organizations.
- Tribal notification letters were distributed to appropriate federally recognized tribes and non-federally recognized tribes.
- Postcards were mailed to over 800 recipients on the project mailing list, including individuals; nongovernmental organizations; community and business groups; fishing, aviation, and recreation groups, and private companies.
- Press releases and a Public Service Announcement to announce the availability of the Draft EIS/OEIS and public meetings were distributed.
- Newspaper advertisements to announce the availability of the Draft EIS/OEIS and public meetings were placed in five area newspapers.
- Four public meetings were held in Hawaii, and one in San Diego, California.

Changes in this Final EIS/OEIS reflect comments made on the Draft EIS/OEIS during the public comment period. Appendix H (Public Comment Responses) describes the public's participation and includes a list of the agencies and private entities that commented on the Draft EIS/OEIS and a comment matrix with Navy responses associated with the comments received.

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ABBREVIATIONS AND ACRONYMS

ACRONYM	DEFINITION
AHPA	Archeological and Historic Preservation Act
AIRFA	American Indian Religious Freedom Act
ARPA	Archaeological Resources Protection Act
ASA	Abandoned Shipwreck Act
CFR	Code of Federal Regulation
CZM	Coastal Zone Management
DEIS	Draft Environmental Impact Statement
DoD	Department of Defense
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FEIS	Final Environmental Impact Statement
HSTT	Hawaii-Southern California Training and Testing
MMPA	Marine Mammal Protection Act
NAGPRA	Native American Graves Protection and Repatriation Act
Navy	U.S. Department of the Navy
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
OEIS	Overseas Environmental Impact Statement
OPAREA	Operating Area
PIRO	Pacific Islands Regional Office
PTS	Permanent Threshold Shift
SEL	Sound Exposure Level
SHPO	State Historic Preservation Officer
SLA	Submerged Lands Act
SMCA	Sunken Military Craft Act
SPL	Sound Pressure Level
TTS	Temporary Threshold Shift
U.S.C.	United States Code
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service

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1 PURPOSE AND NEED

1.1 INTRODUCTION

The United States (U.S.) Department of the Navy (Navy) proposes to conduct military readiness training activities (hereinafter referred to as "training") and research, development, testing, and evaluation (hereinafter referred to as "testing") activities in the Hawaii-Southern California Training and Testing (HSTT) Study Area, as represented in Figure 1.1-1. When discussed together, training and testing are also referred to as "military readiness activities." These military readiness activities include the use of active sonar and explosives at sea off the coasts of Hawaii and Southern California, on the high seas during vessel transit between these areas, in the Temporary Operating Area north and west of the Hawaii Range Complex, and at select Navy pierside and harbor locations. These military readiness activities are generally consistent with those analyzed in the HSTT Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS) completed in December 2013 and are representative of training and testing that the Navy has been conducting in the HSTT Study Area for decades.

The United States is facing increased global disorder—characterized by decline in the long-standing rules-based international order—creating a more complex and volatile security environment. Major conflicts, terrorism, outlaw actions, and natural disasters all have the potential to threaten national security of the United States. The security, prosperity, and vital interests of the United States are increasingly tied to other nations because of the close relationships between the United States and other national economies. The Navy operates on the world's oceans, seas, and coastal areas—the international maritime domain—on which 90 percent of the world's trade and two-thirds of its oil are transported. The majority of the world's population also lives within a few hundred miles of an ocean. The U.S. Navy carries out training and testing activities to be able to protect the United States against its potential adversaries, to protect and defend the rights and interests of the United States and its allies to move freely on the oceans, and to provide humanitarian assistance.

The Navy has historically used the areas around the Hawaiian Islands, as well as those areas near San Diego and areas off the coast of Southern California, for training and testing. These areas have been designated by the Navy as "range complexes." Range complexes provide controlled environments where military ship, submarine, and aircraft crews can train in realistic conditions while safely deconflicting with non-military activities, such as civilian shipping and aircraft. The combination of undersea ranges and operating areas (OPAREAs) with land training ranges, divert airfields, and nearshore amphibious landing sites is critical to realistic training and testing. Electronics on the ranges capture important data on the effectiveness of tactics and equipment–data that provide a feedback mechanism for training evaluation. While these at-sea areas provide ideal training and testing environments for the Navy, these areas are shared with civilian and commercial vessels and aircraft; these are not areas over which the Navy has exclusive control.

A ***range complex*** is a set of adjacent areas of sea space, undersea space, and overlying airspace delineated for military training and testing activities. A ***test range*** is airspace or water surface areas where the Navy conducts a concentrated amount of testing activities. ***Divert airfields*** are airfields on land that are available for emergency use by aircraft operating at sea. Aircraft training activities at sea are typically conducted within 150 nautical miles of a divert airfield.

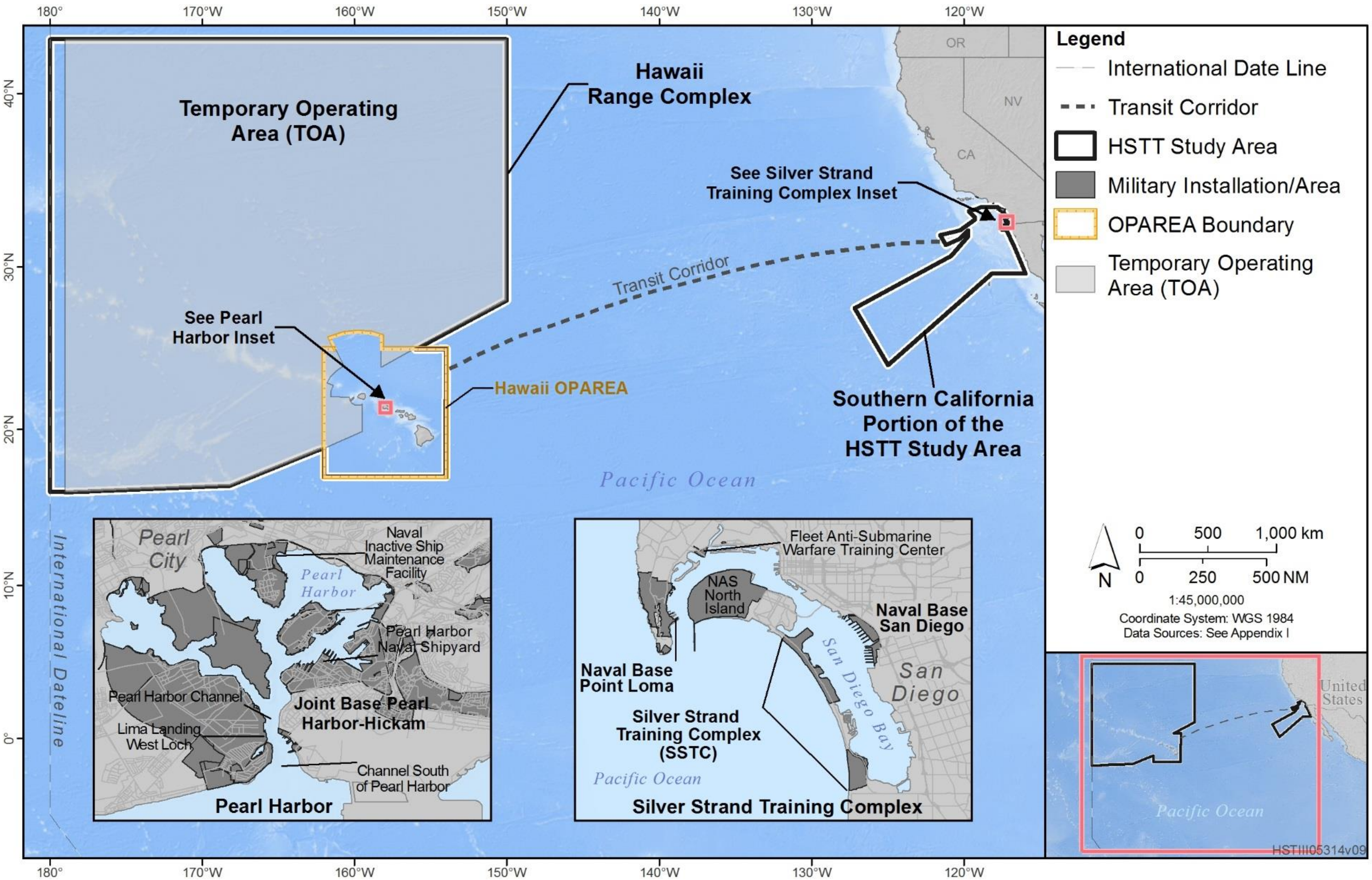

Figure 1.1-1: Hawaii-Southern California Training and Testing Study Area

Notes: HSTT = Hawaii-Southern California Training and Testing, NAS = Naval Air Station, NB = Naval Base.
The Hawaii Range Complex is approximately 2,000 nautical miles from the Southern California Range Complex. Typical Navy ship transit time between the two range complexes is 5 to 7 days.

Military readiness activities, which prepare the Navy to fulfill its mission to protect and defend the United States and its allies, have the potential to impact the environment. The Navy prepared this EIS/OEIS to comply with the National Environmental Policy Act (NEPA) and Executive Order 12114, *Environmental Effects Abroad of Major Federal Actions*, by assessing the potential environmental impacts associated with two categories of military readiness activities conducted at sea: training and testing. Collectively, the at-sea areas in this EIS/OEIS are referred to as the HSTT Study Area (Figure 1.1-1).

Training. Naval personnel (Sailors and Marines) first undergo entry-level (or schoolhouse) training, which varies according to their assigned warfare community (aviation, surface warfare, submarine warfare, and special warfare) and the community's unique requirements. Personnel then train within their warfare community at sea in preparation for deployment; each warfare community has primary mission areas (areas of specialized expertise that may involve or overlap with multiple warfare communities) that are described in detail in Chapter 2 (Description of Proposed Action and Alternatives).

Testing. The Navy researches, develops, tests, and evaluates new platforms[1], systems, and technologies, collectively known as testing. Many tests require realistic conditions at sea and can range from testing new software to complex operations of multiple systems and platforms. Testing activities may occur independent of or in conjunction with training activities.

1.2 The Navy's Environmental Compliance and At-Sea Policy

In 2000, the Navy completed a review of its environmental compliance requirements for exercises and training at sea. The Navy then instituted the "At-Sea Policy" to ensure compliance with applicable environmental regulations and policies, and preserve the flexibility necessary for the Navy and Marine Corps to train and test at sea. This policy directed, in part, that Fleet Commanders develop a programmatic approach to environmental compliance at sea for ranges and OPAREAs within their respective geographic areas of responsibility (U.S. Department of the Navy, 2000). Those ranges affected by the "At-Sea Policy" are designated water areas, sometimes containing instrumentation, that are managed and used to conduct training and testing activities. Some ranges are further broken down into OPAREAs, to better manage and deconflict military readiness activities.

In 2005, the Navy and the National Oceanic and Atmospheric Administration reached an agreement on a coordinated programmatic strategy for assessing certain environmental effects of military readiness activities at sea. The Navy is currently in the third phase of implementing this programmatic approach.

Phase I of environmental planning. The first phase of the planning program was accomplished by the preparation and completion of individual or separate environmental documents for each range complex and OPAREA. The Navy prepared NEPA/Executive Order 12114 documents for three ranges, including the Hawaii Range Complex, Southern California Range Complex, and Silver Strand Training Complex—as well as NEPA documents for other activities in the Study Area—that analyzed training and testing activities. These range complexes pre-date World War II and have been used by U.S. naval forces continuously since then for training and testing activities. Phase I NEPA/Executive Order 12114 documents catalogued training and testing activities; analyzed potential environmental impacts; and supported other requirements under applicable environmental laws, regulations, and executive orders.

[1] Throughout this EIS/OEIS, ships, submarines, and aircraft may be referred to as "platforms;" and weapons, combat systems, sensors, and related equipment may be referred to as "systems."

For example, Marine Mammal Protection Act (MMPA) (16 U.S. Code [U.S.C.] sections 1361–1407) incidental take authorizations and incidental take statements under the Endangered Species Act (ESA) (16 U.S.C. sections 1531–1544) were issued by the National Marine Fisheries Service (NMFS) to the Navy for the Hawaii Range Complex and Southern California activities; those authorizations began expiring in early 2014.

Phase II of environmental planning. The second phase of the Navy's environmental compliance planning covered activities and existing ranges and OPAREAs previously analyzed in the Phase I NEPA/Executive Order 12114 documents and additional geographic areas including, but not limited to, pierside locations and a transit corridor. The Phase II EIS/OEIS for HSTT combined the separate Hawaii Range Complex, Southern California, and Silver Strand Training Complex EISs/OEISs from Phase I into one comprehensive environmental planning document. Specifically, the Study Area (Figure 1.1-1) combined the geographic scope of the in-water areas of the Hawaii Range Complex, Southern California, and Silver Strand Training Complex documents[2], and analyzed ongoing, routine at-sea activities that occur during transit between these range complexes and OPAREAs. The Navy also included new platforms and systems not addressed in previous NEPA/Executive Order 12114 documents. As was done in Phase I, the Navy used this analysis to support regulatory consultations and requests for letters of authorization (set to expire in 2018) under the MMPA and incidental take statements under the ESA.

Phase III of environmental planning. The third phase of the Navy's environmental compliance planning covers similar types of Navy training and testing activities in the same Study Area analyzed in Phase II. The Navy has re-evaluated impacts from these ongoing activities in existing ranges and OPAREAs, to include activities that occur during transit between these range complexes and OPAREAs. The Navy has also analyzed new or changing military readiness activities into the reasonably foreseeable future based on evolving operational requirements, including those associated with new platforms and systems not previously analyzed. The Navy has thoroughly reviewed and incorporated into this analysis the best available science relevant to analyzing the environmental impacts of the proposed activities. The Navy will use this new analysis to support environmental compliance with other applicable environmental laws, such as the MMPA and ESA.

1.3 PROPOSED ACTION

The Navy's Proposed Action, described in detail in Chapter 2 (Description of Proposed Action and Alternatives), is to conduct military readiness activities within existing range complexes and OPAREAs located along the coast of Southern California and around the Hawaiian Islands (Figure 1.1-1). Navy OPAREAs include a transit corridor and designated ocean areas near fleet homeports.

> Title 10 section 5062 of the U.S. Code provides: "The Navy shall be organized, trained, and equipped primarily for prompt and sustained combat incident to operations at sea. It is responsible for the preparation of naval forces necessary for the effective prosecution of war except as otherwise assigned and, in accordance with integrated joint mobilization plans, for the expansion of the peacetime components of the Navy to meet the needs of war."

[2] These documents, which assess associated land-based activities, remain relevant documents. These assessments and the related Biological Opinions are still applicable. In addition, the 2015 Final Environmental Assessment for Joint Logistics Over the Shore, Maritime Prepositioning Force, and Field Exercise Training remains valid as it pertains to analysis of the on-land component of the Elevated Causeway System activity.

1.4 PURPOSE AND NEED

The Navy and NMFS (as a cooperating agency) have coordinated from the outset and developed this document to meet each agency's distinct NEPA obligations and support the decision making of both agencies. The Navy's purpose for the Proposed Action is to ensure that the Navy meets its mission, which is to maintain, train, and equip combat-ready naval forces capable of winning wars, deterring aggression, and maintaining freedom of the seas. This mission is achieved in part by conducting training and testing within the Study Area in accordance with established Navy military readiness requirements. The sections that follow provide a description of the need for military readiness activities.

The Navy has requested authorization to take marine mammals incidental to conducting their training and testing activities in the Study Area by Level A and B harassment, serious injury, and/or mortality. Take under the MMPA is defined as "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal." For military readiness activities, harassment is defined as "(i) any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild [Level A harassment] or (ii) any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering, to a point where such behavioral patterns are abandoned or significantly altered [Level B harassment]."

NMFS has issued proposed regulations and is considering issuance of subsequent Letters of Authorization (LOAs) under section 101(a)(5)(A) of the Marine Mammal Protection Act of 1972, as amended (MMPA; 16 U.S.C. 1361 et seq.) that would govern the taking of marine mammals incidental to the Navy training and testing activities within the Study Area. The issuance of regulations and associated LOAs to the Navy is a major federal action requiring NMFS to analyze the effects of their issuance on the human environment pursuant to NEPA requirements and National Oceanic and Atmospheric Administration policies.

The purpose of issuing incidental take authorizations is to provide an exception to the take prohibition in the MMPA and to ensure that the action complies with the MMPA and implementing regulations. Incidental take authorizations may be issued as either: (1) regulations and associated LOAs under section 101(a)(5)(A) of the MMPA or (2) Incidental Harassment Authorizations (IHAs) under section 101(a)(5)(D) of the MMPA. An Incidental Harassment Authorization can be issued only when there is no potential for serious injury or mortality or where any such potential can be negated through required mitigation measures. Because some of the activities under the Proposed Action may create a potential for lethal takes or takes that may result in serious injury that could lead to mortality, the Navy is requesting rulemaking and the issuance of LOAs for this action.

NMFS's purpose is to evaluate the Navy's proposed action pursuant to NMFS's authority under the MMPA, and to make a determination whether to issue incidental take regulations and LOAs, including any conditions needed to meet the statutory mandates of the MMPA. To authorize the incidental take of marine mammals, NMFS evaluates the best available scientific information to determine whether the take would have a negligible impact on the affected marine mammal species or stocks and an unmitigable impact on their availability for taking for subsistence uses (not relevant here for Navy's proposed action). NMFS must also prescribe permissible methods of taking, other "means of effecting the least practicable adverse impact" on the affected species or stocks and their habitat, and monitoring and reporting requirements. NMFS cannot issue an incidental take authorization unless it can make the required findings. The need for NMFS's action is to consider the impacts of the Navy's activities on marine mammals and meet NMFS' obligations under the MMPA. This Final EIS analyzes the environmental impacts associated with issuance of the requested authorization of the take of marine mammals incidental to the training and testing activities within the Study Area, to include a variety of mitigation measures that were considered during the MMPA authorization process. The analysis of mitigation measures considers benefits to species or stocks and their habitat, and analyzes the practicability and efficacy of each measure. This analysis of mitigation measures was used to support requirements pertaining to mitigation, monitoring, and reporting that would be specified in final MMPA regulations and subsequent LOAs.

1.4.1 Why the Navy Trains

As described above, the Navy is statutorily mandated to protect U.S. national security by being ready, at all times, to effectively prosecute war and defend the nation by conducting operations at sea. The Navy is essential to protecting U.S. national interests considering that 70 percent of the earth is covered in water, 80 percent of the planet's population lives within close proximity to coastal areas, and 90 percent of global commerce is conducted by sea. Naval forces must be ready for a variety of military operations to deal with the dynamic, social, political, economic, and environmental issues that occur in today's rapidly evolving world. Through its continuous presence on the world's oceans the Navy can respond to a wide range of situations because, on any given day, over one-third of its ships, submarines, and aircraft are deployed overseas. Units must be able to respond promptly and effectively while forward deployed. This presence helps to dissuade aggression, which prevents conflict escalation, and provides the President with options to promptly address global contingencies. Before deploying, naval forces must train to develop a broad range of capabilities to respond to threats, from full-scale armed conflict in a variety of different geographic areas and environmental conditions to humanitarian assistance and disaster relief efforts. This also prepares Navy personnel to be proficient in operating and maintaining the equipment, weapons, and systems they will use to conduct their assigned missions. The training process provides personnel with an in-depth understanding of their individual limits and capabilities; the training process also helps the testing community improve new weapon systems' capabilities and effectiveness.

Modern weapons bring both unprecedented opportunities and challenges to the Navy. For example, precision (or smart) weapons help the Navy accomplish its mission with greater accuracy with far less collateral damage than in past conflicts; however, modern weapons are also very complex to use. Military personnel must train regularly with these weapons to understand the capabilities, limitations, and operations of the platform or system, as well as how to keep them operational under difficult conditions and without readily available technical or logistical assistance.

Modern military actions require teamwork among hundreds or thousands of people, across vast geographic areas, and the coordinated use of various equipment, ships, aircraft, and vehicles (e.g., unmanned aerial systems) to achieve success. Personnel increase in skill level by completing basic and specialized individual military training; they advance to intermediate (e.g., unit-level training) and larger exercise training events, which culminate in advanced, integrated training composed of large groups of personnel and, in some instances, joint or combined exercises.[3]

Military readiness training must be as realistic as possible to provide the experiences vital to success and survival during military operations because simulated training, even in technologically advanced simulators, cannot duplicate the complexity faced by Sailors and Marines in the real world. While simulators and synthetic training are critical elements that provide early skill repetition and enhance

[3] Large group exercises may include carrier strike groups, expeditionary strike groups, other U.S. services, and other nations.

teamwork, there is no substitute for live training in a realistic environment. Just as a pilot would not be ready to fly solo after simulator training, a Navy commander cannot allow military personnel to engage in military operations based merely on simulator training.

The large size of the range complex is essential to allow for realistic training scenarios that prepare Sailors and Marines for real-world operations. Only a large range complex offers the space necessary for operations such as the launch and recovery of aircraft or replenishment maneuvers, which require a straight line course at a fixed speed for a sustained period of time. For example, in light wind conditions, to maintain a safe wind speed over the carrier's deck of 20 knots, flight operations taking 30–60 minutes would require traveling in a straight line over a distance of at least 10–20 nautical miles (NM) before any restrictive boundary was approached. Furthermore, multiple fixed wing aircraft landing on an aircraft carrier must be organized into a holding pattern, typically located 10–50 NM distance from the carrier, depending on several factors, including weather conditions, visibility, the number of aircraft waiting to land, and the condition of the aircraft (e.g., fuel remaining). To practice this maneuver safely away from civilian airspace, the carrier would need to be 20–50 NM away from any OPAREA boundary. In short, safe and effective Navy training often requires expansive operating areas due to a number of complex and interrelated factors.

The Navy also requires extensive areas of ocean to conduct its training in order to properly separate and coordinate different training events so that individual training events do not interfere with each other or with public and commercial vessels and aircraft. For example, hazardous activities such as gunnery or missile fire from a vessel in one training event would need to be conducted away from other training events. Additionally, large areas of ocean are required to ensure different training events can be conducted safely while minimizing the risks inherent in military training, such as aircraft flying too closely to one another or to commercial airways. Navy ships must also train to operate at long distances—often hundreds of miles—from each other while still maintaining a common picture of the "battlespace" so that individual Navy units can be coordinated to achieve a common objective. Separation of Navy units may also be required to ensure that participants of other exercises do not experience interference with sensors.

This need for expansive sea space is even more critical today as the Navy has a renewed emphasis on "sea control," which is the need to secure large areas of oceans from other highly capable naval forces. When the Cold War ended, the Navy emerged unchallenged and dominant. That dominance allowed the Navy to focus on projecting power ashore. The balance between sea control and power projection tipped strongly in favor of the latter, and the Navy's surface force evolved accordingly. The Navy's proficiency in land-attack and maritime security operations reached new heights, while foundational skills in anti-submarine warfare and anti-surface warfare slowly began to erode. The emergence of more sophisticated capabilities by potential adversaries will require the Navy to operate further from their coastline in times of conflict, and the modernization of navies able to challenge the U.S. Navy directly means that control of the seas can no longer be assumed. In response, the Navy is developing a model of "distributed lethality," which is intended to enhance the offensive power of individual surface ships. The concept of distributed lethality enables the goal of sea control where and when needed. It is achieved by increasing the offensive and defensive capability of individual warships, employing them in dispersed formations across a wide expanse of geography (e.g., hundreds of thousands of square miles). Extensive areas of ocean are required to effectively conduct distributed lethality training.

1.4.2 OPTIMIZED FLEET RESPONSE PLAN

The Fleet Response Plan that the Navy operated under during Phase I and II emphasized constant readiness. The Fleet Response Plan identified the number of personnel and vessels that had to be ready to deploy on short notice (i.e., surge) in order to respond to rapidly evolving world events. For example, the Fleet Response Plan mandated that the Navy be able to deploy six aircraft carrier strike groups[4] within three months of a crisis and follow those with two more strike groups within three months after the first six deployed. Additionally, the Fleet Response Plan was based on a notional maintenance schedule and strike group deployments of six months in length and approximately 27 months between deployments. However, due to world events and the need for naval forces to be located overseas, Navy vessels were actually deployed for longer periods, resulting in longer maintenance periods. The Fleet Response Plan no longer represented actual fleet readiness preparation.

In December 2014 the Navy initiated the Optimized Fleet Response Plan (Figure 1.4-1), which reinforces the three tenets of "Warfighting First – Operate Forward – Be Ready" (U.S. Department of the Navy, 2014a). The Optimized Fleet Response Plan achieves this by better aligning manning distribution with operational requirements; optimizing maintenance and modernization plans; improving the overall quality of work and life balance for personnel; and ensuring that forces deploy with the right capabilities, properly trained and equipped to meet mission objectives. Like the previous plan, the Optimized Fleet Response Plan maintains a surge requirement by sustaining readiness of deployment-certified forces to enable three aircraft carrier strike groups in both the Atlantic and Pacific Oceans to respond to a national crisis. The Optimized Fleet Response Plan is now based on notional seven-month deployments and approximately 36 months between deployments. Following the Optimized Fleet Response Plan allows the Navy to respond timely to global events with the proper forces while maintaining a structured process that ensures continuous availability of trained, ready Navy forces.

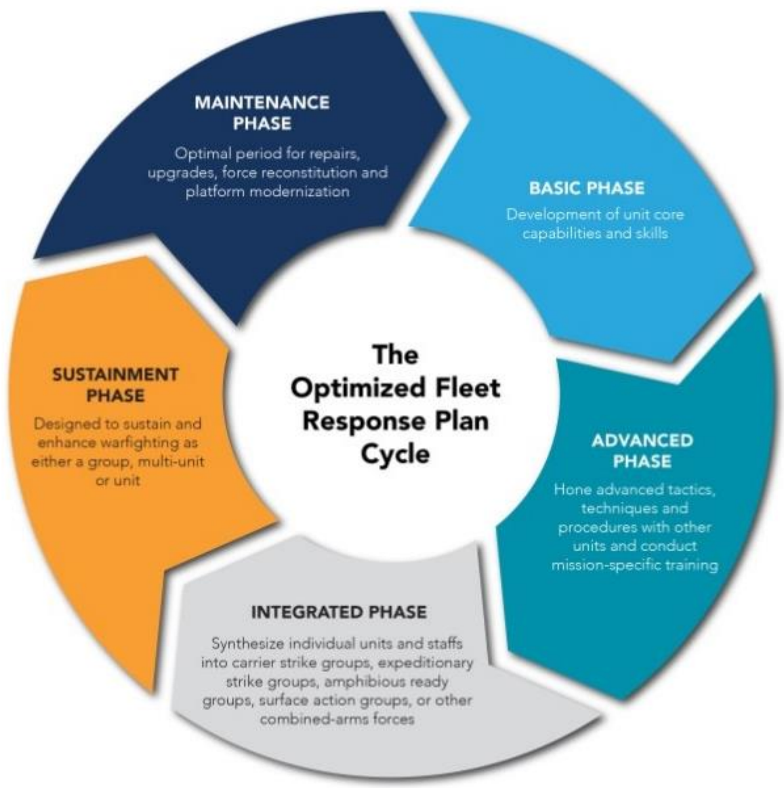

Figure 1.4-1: Optimized Fleet Response Plan

The Optimized Fleet Response Plan outlines the training activities required to achieve a state of military readiness that will allow Navy personnel to execute operations as ordered by their commanders, to

[4] While strike groups could be configured differently, a typical aircraft carrier strike group would include an aircraft carrier, a guided missile cruiser, two guided missile destroyers, an attack submarine, and a supply ship.

include responding to a conflict. The plan uses a building-block approach where initial basic training complements later phases of more complex training, with each phase building upon the skills obtained in the previous phase. Specifically, training activities proceed in five phases: maintenance, basic, advanced, integrated, and sustainment, as depicted in Figure 1.4-1. The training events that occur in each of these phases are designed to prepare Sailors for the multitude of contingencies they may face, ranging from large strike group level activities such as defending against submarine or mine threats, conducting long-range bombing missions, putting Marines ashore in a hostile environment to humanitarian responses for natural catastrophes such as earthquakes and hurricanes. To ensure Sailors and Marines can perform the variety of missions they could face, the training building blocks are designed to maximize their effectiveness at accomplishing the mission safely and professionally.

The Optimized Fleet Response Plan cycle starts at the beginning of the maintenance phase and ends upon the beginning of the next maintenance phase, as detailed below. Readiness increases throughout the cycle and culminates with the highest level of readiness at the end of the integrated or advanced phase.

1.4.2.1 Maintenance Phase

The beginning of the maintenance phase signals the start of the Optimized Fleet Response Plan cycle. The goal of this phase is on-time completion of maintenance and modernization so that units are able to begin training and adhere to the Optimized Fleet Response Plan training schedule. All deployable Navy forces have a maintenance phase, which varies among different types of forces. The maintenance phase is critical to the success of the Optimized Fleet Response Plan since this represents the ideal time for major shipyard repairs, upgrades, and platform modernization. Also during this phase, Navy forces will complete required inspections, certifications, assist visits, and individual and team training to achieve required levels of personnel, equipment, supply, and ordnance readiness.

1.4.2.2 Basic Phase

The intent of the basic phase is to focus on the development of core capabilities and skills through the completion of basic-level training, inspections, certifications, and assessments. Achieving required levels of personnel, equipment, supply, and ordnance readiness is essential to success in subsequent Optimized Fleet Response Plan phases. Units that have completed all basic phase requirements are ready for more complex training and are capable of independent operations in support of homeland security, humanitarian assistance, and disaster relief missions.

The basic phase consists of training exercises performed by individual ships and aircraft and is mostly characterized as unit-level training. Unit-level training focuses on fundamental combat skills for a unit, such as an individual ship. Operating area and range support requirements for unit-level training are relatively modest compared to large-scale, major exercises. Coordinated unit-level exercises involve two or more units, such as ships, aircraft, or both, and are also included in the basic phase. These exercises further refine the basic, fundamental skills while increasing difficulty by requiring coordination with other units.

Due to the repetition required in unit-level training, proximity of local range complexes to the locations where Sailors and Marines are stationed is important, as it reduces the amount of travel time and training costs during the basic phase of training. Access to local ranges also increases the time these Sailors and Marines can spend at home, with their families and communities before going on long deployments.

Ships and aircraft conducting basic phase training are likely operating in the same range complex or OPAREA where other units are conducting unrelated activities in the basic phase, integrated phase, or sustainment phase. Without sufficiently sized OPAREAs, this necessary, simultaneous training could not occur.

1.4.2.3 Advanced Phase

The purpose of the advanced phase is to build on unit warfighting capabilities through academic, synthetic, and live training in advanced training, tactics, and procedures in all mission areas within a challenging warfighting environment. This phase provides an opportunity to hone advanced training, tactics, and procedures with other units and conduct mission-specific training to meet mission requirements while maintaining proficiency attained in the basic phase. The advanced phase provides a sufficient block of time to complete required inspections, certifications, assessments, visits and training. This phase includes attainment of acceptable unit warfighting proficiency in all required mission areas and completion of mission-specific training for identified mission sets. Upon completion of the advanced phase, most Navy forces will aggregate into a strike group, amphibious ready group, or other combined arms force and commence the integrated phase of training. Occasionally, forces will not conduct an integrated phase of training because, for example, they will be ordered to deploy independently (separate from a strike group or amphibious ready group). In those instances, these units will be certified to deploy following the advanced phase.

1.4.2.4 Integrated Phase

The goal of the integrated phase is to provide these units and staffs advanced warfare skills in a challenging, multidimensional, and realistic threat warfare environment. This phase allows members of a combined force to build on individual and unit-level skills and conduct multi-unit in-port and at-sea training, culminating in an assessment of their performance under high-end and high-stress realistic threat conditions. The integrated phase combines the units that have completed the advanced phase of training into strike groups (such as an Amphibious Ready Group). Strike groups are composed of multiple ships and aircraft operating together but covering many, sometimes thousands of square miles to simulate a real-world situation. For example, a strike group may be expected to operate in coordinated fashion in the entire Persian Gulf or Mediterranean Sea. Major exercises in this phase require access to large, relatively unrestricted areas of ocean and airspace, multiple targets, and unique range attributes (complex and varying oceanographic features, close proximity to naval bases, and land-based targets).

The integrated phase concludes with certification for deployment, meaning that the strike group has demonstrated the skills and proficiencies across the entire spectrum of warfare that may be needed during deployment.

1.4.2.5 Sustainment Phase

The sustainment phase includes all activities and training following certification for deployment until the next maintenance phase begins. The goal of the sustainment phase is to provide strike groups with training that allows forces to maintain their highest level of readiness and proficiency, as well as the ability to evaluate new and developing technologies, and evaluate and develop new tactics. The strike group needs to continue training after certification for deployment and upon return from deployment up until it enters the maintenance phase, to maintain its perishable skills.

Similar to the integrated phase, sustainment exercises require access to large, relatively unrestricted areas of ocean and airspace and unique range attributes to support the scenarios.

Ships and aircraft conducting sustainment phase training are likely operating in the same range complex or OPAREA where other units are conducting unrelated activities in the basic phase, advanced phase, integrated phase, or sustainment phase. Without sufficiently sized OPAREAs, this necessary, simultaneous training could not occur.

1.4.3 Why the Navy Tests

The Navy's research and acquisition community, including research funding organizations, laboratory facilities, and systems commands, are responsible for providing weapons, systems, and platforms for the men and women of the Navy that support their missions and give them a technological edge over the United States' adversaries. This community is at the forefront of researching, developing, testing, evaluating, acquiring, and delivering modern platforms, systems, and related equipment to meet fleet capability and readiness requirements while providing the necessary high return on investment to the American taxpayer. The Navy's research funding organizations and laboratories concentrate primarily on the development of new science and technology and include the initial testing of concepts that are relevant to the Navy of the future. The results of these research efforts carry forward to the ship, aircraft, and weapon system products developed by systems commands, who support the full lifecycle of product and service delivery from research and development, to testing, acquisition, and deployment, to operations and logistics support, including maintenance, repair, and modernization of Navy platforms (e.g., ships, aircraft), weapon systems, and components. Testing begins at the research and development phase and continues through to the final certification of systems and hardware. For example, the building of a new ship would involve the development of all the software and hardware systems within the ship, the construction of the ship itself, and testing the ship's seaworthiness and operation of its systems. After delivery to the fleet, the testing community supports maintenance, provides updates to software and hardware systems, and may include training Sailors on the operation of the ship's systems.

The Navy's research, acquisition, and testing community includes the following:

- Naval Air Systems Command, which develops, acquires, delivers, and sustains naval aviation aircraft, weapons, and systems with proven capability and reliability to ensure Sailors and Marines achieve mission success.

- Naval Sea Systems Command, which develops, acquires, delivers, and maintains surface ships, submarines, unmanned vehicles, and weapon system platforms that provide the right capability to the Sailors and Marines.

- Office of Naval Research, which is a research funding organization that plans, fosters, encourages, and conducts a broad program of scientific research (at universities, industry, small business, etc.), that promotes future naval sea power, enhances national security, and meets the complex technological challenges of today's world. The Office of Naval Research is also a parent command for the Naval Research Laboratory, which operates as the Navy's corporate research laboratory and conducts a multidisciplinary program of scientific research.

- Space and Naval Warfare Systems Command, which provides the Sailor with knowledge superiority by developing, delivering, and maintaining effective, capable, and integrated command, control, communications, computer, intelligence, and surveillance systems.

The Navy's systems commands design, test, and build component, system, and platforms to address requirements identified by the fleet. The Navy's systems commands must test and evaluate the platform, system, or upgrade to validate whether it performs as expected and to determine whether it is operationally effective, suitable, survivable, and safe for its intended use by the fleet.

1.4.3.1 Types of Testing

Testing performed by the Navy's research and acquisition community can be categorized as scientific research testing, performance and specification testing, developmental testing, operational testing, fleet training support, follow-on test and evaluation, lot acceptance testing, or maintenance and repair testing. Fleet training events often offer the most suitable environment for testing a system because training events are designed to accurately replicate operational conditions. Testing, therefore, is often embedded in fleet training events such that distinguishing a testing event from a training event would be difficult for an observer, as the only difference could be the purpose for which the activity was being conducted. Categories of testing events include:

- **Scientific research testing.** Scientific research testing is required to evaluate emerging threats or technology enhancement before development of a new system. As an example, testing might occur on a current weapon system to determine if a newly developed technology would improve system accuracy or enhance safety to personnel. Additionally, scientific research involves the use of devices to measure the properties of the environment in which a system may operate. For example, acoustic propagation experiments are conducted in particular environments to see how far acoustic signals produced by current and future operational systems could travel. Other research activities involve the transmission of acoustic signals designed to convey information from one platform to another. This "acoustic communication" is also very dependent on environmental conditions and needs to be studied where a variety of these conditions occur.

- **Performance and specification testing.** Performance and specification tests are required prior to Navy acceptance of a new system or platform. These tests may be conducted in a Navy Range Complex or at pierside locations; these tests are sometimes done in conjunction with fleet training activities.

- **Developmental testing.** Developmental tests are conducted to assist in the design of a platform or system, and to ensure that technical performance specifications have been met. For example, a weapon system may be tested using prescribed settings (e.g., a specific run pattern) to ensure the full range of system parameters can be met.

- **Operational testing.** Operational tests are conducted by specialized Navy units to evaluate the platform or system under conditions as it would be used by the fleet during operations. For example, a weapons system may be tested without prearranged settings, such that the specialized unit conducting the test can make adjustments as necessary for the prevailing conditions.

- **Fleet training support.** Fleet training support is conducted when systems still under development may be integrated on ships or aircraft for testing, and new platforms and systems are transitioned to the fleet once they are ready for operational use. During this effort, the Navy's systems commands may provide training on the operation, maintenance, and repair of the system during developmental testing activities.

- **Follow-on test and evaluation.** A follow-on test and evaluation occurs when a platform receives a new system, after a significant upgrade to an existing system, or when the system failed to meet performance specifications during previous testing. Follow-on tests and evaluations ensure that the modified or new system meets performance requirements and does not conflict with existing platform systems and subsystems.

- **Lot acceptance testing.** Lot acceptance tests evaluate systems from the Department of Defense contractor's production line to ensure that the manufacturer is producing systems that conform to specifications and perform as designed. Lot acceptance testing serves as the Navy's quality control check of the system before it is delivered to the fleet.

- **Maintenance and repair testing.** Following periodic maintenance, overhaul, modernization, or repair of systems, testing of the systems may be required to assess performance. These testing activities may be conducted at sea, in shipyards, or at Navy piers.

Preparatory checks of a platform or system are often made during Navy repair and construction activities prior to actual testing to ensure the platform or system is operating properly before expending the often-considerable resources involved in conducting a full-scale test. For example, a surface combatant may conduct a functional check of its hull-mounted sonar system in a nearshore area before conducting a more rigorous test of the sonar system farther offshore.

1.4.3.2 Methods of Testing

The Navy uses a number of different testing methods, including computer simulation and analysis, as well as at-sea testing, throughout the development of platforms and systems. Although computer simulation is a key component in the development of platforms and systems, it cannot provide information on how a platform or system will perform or whether it will be able to meet performance and other specification requirements in the environment in which it is intended to operate. Actual performance data are needed. For this reason, platforms and systems must undergo at-sea testing at some point in the development process. Thus, as with fleet training, the research and acquisition community requires access to large, relatively unrestricted ocean OPAREAs, multiple strike targets, and unique range attributes to support its testing requirements.

Navy platforms and systems must be tested and evaluated within the broadest range of operating conditions available (e.g., bathymetry, topography, geography, oceanographic conditions) because Navy personnel must be capable and confident to perform missions within the wide range of conditions that exist worldwide.

However, forecasting when technologies will be mature for testing is not easy. Programs and projects that have successfully completed the research and development stage and are determined mature enough to transition into an official, fully funded program have more defined test requirements. However, programs and projects are still subject to fiscal constraints and technical challenges that can often delay their development or even cancel continuation. Technical issues can require that systems or platforms undergo additional tests. Continued upgrades and maintenance of systems may occur on variable schedules due to availability, emergent requirements, or unforeseen system issues. Therefore, the types, amounts, and locations of testing activities may vary across different programs and projects in any given year. For all of these reasons, capturing the future testing requirements for platform, weapons, and system programs is challenging and reflects the system commands' best estimation based on historical and current best available information. To ensure comprehensive environmental impact analysis in this EIS/OEIS, the Navy assumes that all proposed testing projects will proceed as scheduled, with no unexpected delays.

1.5 Overview and Strategic Importance of Existing Range Complexes

The range complexes analyzed in this EIS/OEIS have each existed for many decades, dating back to the 1930s. Range use and infrastructure have developed over time as military readiness requirements in support of modern warfare have evolved. The Study Area is the same as that covered in the 2013 HSTT EIS/OEIS; the Navy is not proposing to expand the Study Area.

Proximity of the Hawaii and Southern California Range Complexes to naval homeports and air stations is strategically important to the Navy. Close access allows for efficient execution of military readiness activities including maintenance functions, as well as access to alternate airfields when necessary in order to provide for a margin of safety. Fuel is saved and equipment is exposed to less wear when ranges are near where the platforms are based. The proximity of training to homeports also ensures that Sailors and Marines do not spend unnecessary time away from their families during the training cycle. Additionally, the *Navy Personnel Tempo and Operating Tempo Program* requires the Navy to track and, where possible, limit the amount of time Sailors and Marines spend deployed from home (U.S. Department of the Navy, 2014b). Less time away from home is an important factor in military readiness, morale, and retention. The proximate availability of the Hawaii and Southern California range complexes is critical to Navy efforts in these areas.

The following range complexes, training complex, and sea range are located in the HSTT Study Area and are described in further detail in Section 2.1 (Description of the Hawaii-Southern California Training and Testing Study Area), as depicted in Figure 1.1-1:

- Hawaii Range Complex
- Southern California Range Complex
- Silver Strand Training Complex
- Portion of the Point Mugu Sea Range

1.6 The Environmental Planning Process

This EIS/OEIS is designed to comply with the requirements of both NEPA and Executive Order 12114, *Environmental Effects Abroad of Major Federal Actions,* and support additional legal compliance requirements, as further described below. Since NEPA does not apply globally, President Carter issued Executive Order 12114 in 1979, furthering the purpose of NEPA by creating similar procedures for federal agency activities affecting the environment of the global commons outside U.S. jurisdiction. Thus, the Navy undertakes environmental planning for major Navy actions occurring throughout the world in accordance with applicable laws, regulations, and executive orders.

1.6.1 National Environmental Policy Act Requirements

When developing an EIS, the first step in the NEPA process (Figure 1.6-1) is to prepare a Notice of Intent to develop an EIS. The Notice of Intent is published in the *Federal Register* and in local newspapers, and provides an overview of the proposed action and the scope of the EIS. The Notice of Intent is also the first step in engaging the public, initiating the scoping process.

Scoping is an early and open process for developing the "scope" of issues to be addressed in an EIS and for identifying significant issues related to a proposed action. During this process, the public helps define and prioritize issues that will be analyzed in the EIS.

After the scoping process, a Draft EIS is prepared to assess potential impacts of the proposed action and alternatives on the environment. When completed, a Notice of Availability is published in the *Federal Register* and notices are placed in local or regional newspapers announcing the availability of the Draft EIS. The Draft EIS is circulated for public review and comment. Public meetings may also be scheduled to further inform the public and solicit their comments.

The Final EIS addresses all public comments received on the Draft EIS. Responses to public comments may include factual corrections, supplements or modifications to analysis, and inclusion of new information. Additionally, responses may explain why the comments do not warrant further agency response.

Finally, the decision-maker will issue a Record of Decision no earlier than 30 days after the Final EIS is made available to the public.

For a description of how the Navy complies with each of these requirements during the development of the HSTT EIS/OEIS, please see Chapter 8 (Public Involvement).

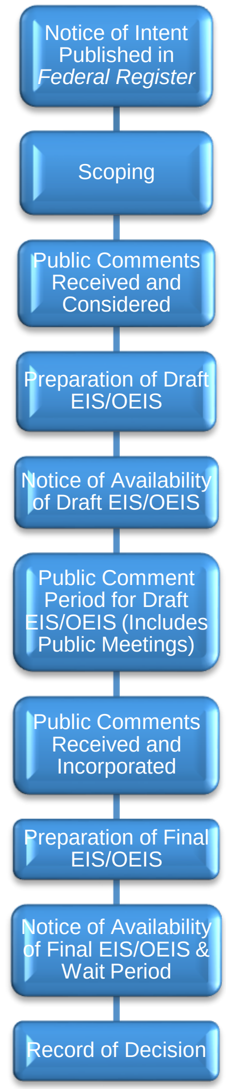

Figure 1.6-1: National Environmental Policy Act Process

1.6.2 Executive Order 12114

Executive Order 12114 of 1979, *Environmental Impacts Abroad of Major Federal Actions*, furthers the purpose of NEPA by directing federal agencies to provide for informed environmental decision making for major federal actions outside the United States and its territories. Presidential Proclamation 5928, issued December 27, 1988, extended the exercise of U.S. sovereignty and jurisdiction under international law to 12 NM; however, the proclamation expressly provides that it does not extend or otherwise alter existing federal law or any associated jurisdiction, rights, legal interests, or obligations. Thus, as a matter of policy, the Navy analyzes environmental effects and actions within 12 NM under NEPA (an EIS) and those effects occurring beyond 12 NM under the provisions of Executive Order 12114 (an OEIS).

1.6.3 Other Environmental Requirements Considered

The Navy must comply with all applicable federal environmental laws, regulations, and executive orders, including, but not limited to, those listed below. Further information can be found in Chapter 6 (Regulatory Considerations).

1.6.3.1 Federal Statutes

The following are federal statutes that are most relevant to the analysis of impacts in this EIS/OEIS.

1.6.3.1.1 Clean Air Act

The purpose of the Clean Air Act (42 U.S.C. sections 7401–7671q) is to protect public health and welfare by the control of criteria air pollution at its source and set forth primary and secondary National Ambient Air Quality Standards to establish criteria for states to attain, or maintain, these minimum standards. Non-criteria air pollutants that can affect human health are categorized as hazardous air pollutants under section 112 of the Clean Air Act. The U.S. Environmental Protection Agency identified 189 hazardous air pollutants such as benzene, perchloroethylene, and methylene chloride. Section 176(c)(1) of the Clean Air Act, commonly known as the General Conformity Rule, requires federal agencies to ensure that their actions conform to applicable state implementation plans for achieving and maintaining the National Ambient Air Quality Standards for criteria pollutants in non-attainment and maintenance areas for criteria pollutants and their precursors.

1.6.3.1.2 Clean Water Act

The Clean Water Act (33 U.S.C. sections 1251–1376) regulates discharges of pollutants in surface waters of the United States. The Uniform National Discharge Standards (40 Code of Federal Regulations [CFR] part 1700) govern discharges incidental to the normal operation of Navy ships at sea.

1.6.3.1.3 Coastal Zone Management Act

The Coastal Zone Management Act of 1972 (16 U.S.C. section 1451, et seq.) encourages coastal states to be proactive in managing coastal zone uses and resources. The act established a voluntary coastal planning program and required participating states to submit a Coastal Management Plan to the National Oceanic and Atmospheric Administration for approval. Under the act, federal actions that have reasonably foreseeable effects on a coastal use or resource are required to be consistent, to the maximum extent practicable, with the enforceable policies of federally approved Coastal Management Plans. The Coastal Zone Management Act defines the coastal zone as extending offshore "to the outer limit of State title and ownership under the Submerged Lands Act."

A consistency determination, a negative determination, or a *de minimis* exemption may be submitted for review of federal agency activities. A federal agency submits a consistency determination when it determines that its activity may have either a direct or an indirect effect on a state coastal use or resource. In accordance with 15 CFR section 930.39, the consistency determination will include a brief statement indicating whether the proposed activity will be undertaken in a manner consistent, to the maximum extent practicable, with the enforceable policies of the management program.

1.6.3.1.4 Endangered Species Act

The ESA of 1973 (16 U.S.C. sections 1531–1544) provides for the conservation of endangered and threatened species and the ecosystems on which they depend. The act defines an endangered species as a species in danger of extinction throughout all or a significant portion of its range. A threatened species is one that is likely to become endangered within the near future throughout all or in a significant portion of its range. The U.S. Fish and Wildlife Service (USFWS) and NMFS jointly administer the ESA and are responsible for listing species as threatened or endangered and for designating critical habitat for listed species. The ESA allows the designation of geographic areas as critical habitat for threatened or endangered species. Section 7(a)(2) requires each federal agency to ensure that any action it authorizes, funds, or carries out is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat of such species. When a federal agency's action "may affect" a listed species, that agency is required to consult with the service (NMFS or USFWS) that has jurisdiction over the species (50 CFR section 402.14(a)). Consultation will conclude with preparation of a biological opinion that determines whether the federal agency action will jeopardize listed species or adversely modify or destroy critical habitat for formal consultation, or when the Services concur, in writing, that a proposed action "is not likely to adversely affect" listed species or designated critical habitat for informal consultation. An incidental take statement is included in every biological opinion where take is anticipated. This incidental take statement allows the proposed action to occur without being subject to penalties under the ESA.

1.6.3.1.5 Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. sections 1801–1882), enacted in 1976 and amended by the Sustainable Fisheries Act in 1996 and the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006, mandates identification and conservation of essential fish habitat. Essential fish habitat is defined as those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity (i.e., full life cycle). These waters include aquatic areas and their associated physical, chemical, and biological properties used by fish, and may include areas historically used by fish. Substrate types include sediment, hard bottom, structures underlying the waters, and associated biological communities. Federal agencies are required to consult with NMFS and to prepare an essential fish habitat assessment if potential adverse effects on essential fish habitat are anticipated from their activities. Any federal agency action that is authorized, funded, undertaken, or proposed to be undertaken that may affect fisheries is subject to the Magnuson-Stevens Fishery Conservation and Management Act.

1.6.3.1.6 Marine Mammal Protection Act

The MMPA of 1972 established, with limited exceptions, a moratorium on the "taking" of marine mammals in waters or on lands under U.S. jurisdiction. The act further regulates "takes" of marine mammals on the high seas by vessels or persons subject to U.S. jurisdiction. The term "take," as defined in section 3 (16 U.S.C. section 1362 (13)) of the MMPA, means "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal." "Harassment" was further defined in the 1994 amendments to the MMPA, which provided two levels of harassment: Level A (potential injury) and Level B (potential behavioral disturbance).

The MMPA directs the Secretary of Commerce (as delegated to NMFS) to allow, upon request, the incidental, but not intentional, taking of small numbers of marine mammals by U.S. citizens or agencies who engage in a specified activity (other than commercial fishing) within a specified geographical region if NMFS finds that the taking will have a negligible impact on the species or stock(s), and will not have an unmitigable adverse impact on the availability of the species or stock(s) for subsistence uses (where relevant). In issuing regulations authorizing the incidental taking, NMFS must set forth the permissible methods of taking, other means of effecting the least practicable adverse impact on the species or stock and its habitat and on the availability of the species or stock for subsistence uses (where relevant), and requirements pertaining to monitoring and reporting of such taking.

The National Defense Authorization Act of Fiscal Year 2004 (Public Law 108-136) amended the definition of harassment, removed the "specified geographic area" requirement, and removed the small numbers provision as applied to military readiness activities or scientific research activities conducted by or on behalf of the federal government consistent with section 104(c)(3) (16 U.S.C. section 1374(c)(3)). The

Fiscal Year 2004 National Defense Authorization Act adopted the definition of "military readiness activity" as codified at 16 U.S.C. 703 Note. A "military readiness activity" is defined as "all training and operations of the Armed Forces that relate to combat" and the "adequate and realistic testing of military equipment, vehicles, weapons, and sensors for proper operation and suitability for combat use." For military readiness activities, the relevant definition of harassment is any act that:

- injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild ("Level A harassment") or
- disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering to a point where such behavioral patterns are abandoned or significantly altered ("Level B harassment") (16 U.S.C. section 1362(18)(B)(i) and (ii)).

1.6.3.1.7 Migratory Bird Treaty Act

The Migratory Bird Treaty Act of 1918 (16 U.S.C. sections 703–712) and the Migratory Bird Conservation Act (16 U.S.C. sections 715–715d, 715e, 715f–715r) of February 18, 1929, are the primary laws in the United States established to conserve migratory birds. The Migratory Bird Treaty Act prohibits the taking, killing, or possessing of migratory birds or the parts, nests, or eggs of such birds, unless permitted by regulation.

The 2003 National Defense Authorization Act provided interim authority to members of the Armed Forces to incidentally take migratory birds during approved military readiness activities without violating the Migratory Bird Treaty Act. The Authorization Act provided this interim authority to give the Secretary of the Interior (Secretary) time to exercise his/her authority under section 704(a) of the Migratory Bird Treaty Act to prescribe regulations authorizing such incidental take. The Secretary delegated this task to the USFWS. On February 28, 2007, the USFWS issued a final military readiness rule authorizing members of the Armed Forces to incidentally take migratory birds during military readiness activities (U.S. Fish and Wildlife Service, 2007).

1.6.3.1.8 National Historic Preservation Act

The National Historic Preservation Act of 1966 (54 U.S.C. section 300101 et seq.) establishes preservation as a national policy and directs the federal government to provide leadership in preserving, restoring, and maintaining the historic and cultural environment. Section 106 of the National Historic Preservation Act requires federal agencies to take into account the effects of their undertakings on historic properties and afford the Advisory Council on Historic Preservation a reasonable opportunity to comment. The National Historic Preservation Act created the National Register of Historic Places, the list of National Historic Landmarks, and the State Historic Preservation Offices to help protect each state's historical and archaeological resources. Section 110 of the National Historic Preservation Act requires federal agencies to assume responsibility for the preservation of historic properties owned or controlled by them and to locate, inventory, and nominate all properties that qualify for the National Register. Agencies shall exercise caution to assure that significant properties are not inadvertently transferred, sold, demolished, substantially altered, or allowed to deteriorate. The National Historic Preservation Act applies to cultural resources evaluated in this EIS/OEIS.

1.6.3.1.9 National Marine Sanctuaries Act

Under the Marine Protection, Research, and Sanctuaries Act of 1972 (also known as the National Marine Sanctuaries Act), the Secretary of Commerce may establish a national marine sanctuary for marine areas with special conservation, recreational, ecological, historical, cultural, archaeological, scientific, educational, or aesthetic qualities. Day-to-day management of national marine sanctuaries has been delegated by the Secretary of Commerce to the National Oceanic and Atmospheric Administration's Office of National Marine Sanctuaries. Once a sanctuary is designated, the Secretary of Commerce may authorize activities in the sanctuary only if they can be certified to be consistent with the National Marine Sanctuaries Act and can be carried out within the regulations for the sanctuary. Regulations exist for each sanctuary, and military activities may be authorized within those regulations. Additionally, the National Marine Sanctuaries Act requires federal agencies whose actions are "likely to destroy, cause the loss of, or injure a sanctuary resource" to consult with the program before taking the action. In these cases, the Office of National Marine Sanctuaries is required to recommend reasonable and prudent alternatives to protect sanctuary resources if the action is likely to destroy, cause the loss of, or injure a sanctuary resource. If the federal agency decides not to follow the recommendations, it must respond in writing to the Office of National Marine Sanctuaries.

1.6.3.2 Executive Orders

The following are Executive Orders that are most relevant to the analysis of impacts in this EIS/OEIS.

1.6.3.2.1 Executive Order 13834, *Efficient Federal Operations*

Executive Order 13834 (83 *Federal Register* 23771) was issued on May 17, 2018 and revoked Executive Order 13693. The goal of Executive Order 13834 is to prioritize actions that reduce waste, cut costs, enhance the resilience of Federal infrastructure and operations, and enable more effective accomplishment of an agency's mission.

1.6.3.2.2 Executive Order 13158, *Marine Protected Areas*

Executive Order 13158 (65 *Federal Register* 34909) was authorized in May 2000 to protect special natural and cultural resources by strengthening and expanding the nation's system of marine protected areas. The purpose of the order is to (1) strengthen the management, protection, and conservation of existing marine protected areas and establish new or expanded marine protected areas; (2) develop a scientifically based, comprehensive national system of marine protected areas representing diverse U.S. marine ecosystems, and the nation's natural and cultural resources; and (3) avoid causing harm to marine protected areas through federally conducted, approved, or funded activities.

1.6.3.2.3 Executive Order 13840, *Ocean Policy to Advance the Economic, Security, and Environmental Interests of the United States*

Executive Order 13840 (83 *Federal Register* 29431) was issued on June 19, 2018. The goal of Executive Order 13840 is to advance the economic, security, and environmental interests of the United States through improved public access to marine data and information; efficient Federal agency coordination on ocean-related matters; and engagement with marine industries, the science and technology community, and other ocean stakeholders, including Regional Ocean Partnerships. This Executive Order revokes and replaces Executive Order 13547.

1.7 Scope and Content

In this EIS/OEIS, the Navy analyzed military readiness training and testing activities that could potentially impact human and natural resources, especially marine mammals, sea turtles, and other marine resources. The range of alternatives includes the No Action Alternative and two action alternatives. In this EIS/OEIS, the Navy analyzed direct, indirect, and cumulative impacts. The Navy is the lead agency for the Proposed Action and is responsible for the scope and content of this EIS/OEIS. The National Oceanic

Atmospheric Administration's NMFS is a cooperating agency because the scope of the Proposed Action and alternatives involves activities that have the potential to impact protected resources under their jurisdiction and for which they have special expertise, including marine mammals, threatened and endangered species, essential fish habitat, and national marine sanctuaries. The National Oceanic Atmospheric Administration's authorities and special expertise is based on its statutory responsibilities under the MMPA, as amended (16 U.S.C. section 1361 et seq.), the ESA (16 U.S.C. section 1531 et seq.), the Magnuson-Stevens Fishery Conservation and Management Act and the National Marine Sanctuaries Act (16 U.S.C. sections 1431–1445c-1). In addition, NMFS, in accordance with 40 CFR sections 1506.3 and 1505.2, intends to adopt this EIS/OEIS and issue a separate Record of Decision associated with its decision to grant or deny the Navy's request for incidental take authorizations pursuant to section 101(a)(5)(A) of the MMPA.

In accordance with the Council on Environmental Quality Regulations, 40 CFR section 1505.2, the Navy will issue a Record of Decision that provides the rationale for choosing one of the alternatives.

1.8 Organization of this Environmental Impact Statement/Overseas Environmental Impact Statement

This EIS/OEIS is organized as follows:

- Chapter 1 describes the purpose of and need for the Proposed Action.
- Chapter 2 describes the Proposed Action, alternatives considered but eliminated in the EIS/OEIS, and alternatives to be carried forward for analysis in the EIS/OEIS.
- Chapter 3 describes the existing conditions of the affected environment and analyzes the potential impacts of the proposed training and testing activities for each alternative.
- Chapter 4 describes the analysis of cumulative impacts, which are the impacts of the Proposed Action when added to past, present, and reasonably foreseeable future actions.
- Chapter 5 describes the protective measures the Navy evaluated that could mitigate impacts to the environment.
- Chapter 6 describes considerations required by NEPA and describes how the Navy complies with other federal, state, and local plans, policies, and regulations.
- Chapter 7 includes a list of preparers of this EIS/OEIS.
- Chapter 8 includes a description of the Navy's public involvement process, including a list of agencies, government officials, tribes, groups, and individuals on the distribution list for receipt of the Draft EIS/OEIS.
- Appendix A provides descriptions of the proposed Navy activities.
- Appendix B shows the relationship of stressors to the activities and to the environmental resources analyzed.
- Appendix C provides air quality emissions calculations and a Record of Non-Applicability.

- Appendix D explains acoustic and explosive concepts.
- Appendix E provides estimates of marine mammals and sea turtle impacts from exposure to acoustic and explosive stressors under Navy training and testing activities.
- Appendix F presents military expended material and direct strike impact analysis.
- Appendix G presents Federal Register notices applicable to this project.
- Appendix H provides responses to public comments.
- Appendix I lists geographic information system data sources.
- Appendix J provides agency correspondence applicable to this project.
- Appendix K provides an assessment of geographic mitigation areas considered or implemented by the Navy.

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REFERENCES

U.S. Department of the Navy. (2000). *Compliance with Environmental Requirements in the Conduct of Naval Exercises or Training at Sea*. Washington, DC: The Under Secretary of the Navy.

U.S. Department of the Navy. (2014a). *Optimized Fleet Response Plan. COMUSFLTFORCOM/ COMPACFLTINST 3000.15A N7. December 8, 2014*. Norfolk, VA and Pearl Harbor, HI: Commander, U.S. Fleet Forces Command and Commander United States Pacific Fleet.

U.S. Department of the Navy. (2014b). *Chief of Naval Operations Instruction 3000.13D, Navy Personnel Tempo and Operating Tempo Program*. Washington, DC: Office of the Chief of Naval Operations.

U.S. Fish and Wildlife Service. (2007). *Migratory Bird Permits; Take of Migratory Birds by the Armed Forces*: U.S. Fish and Wildlife Service.

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Final
Environmental Impact Statement/Overseas Environmental Impact Statement
Hawaii-Southern California Training and Testing

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2 DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES

The United States (U.S.) Department of the Navy (Navy) proposes to conduct training activities (hereinafter referred to as "training"), and research, development, testing, and evaluation (hereinafter referred to as "testing") activities in the Hawaii-Southern California Training and Testing (HSTT) Study Area, as represented in Figure 2.1-1. When discussed together, training and testing are also referred to as "military readiness activities." These military readiness activities include the use of active sonar and explosives at sea off the coasts of Hawaii and Southern California, on the high seas during vessel transit between these areas, in the Temporary Operating Area north and west of the Hawaii Operating Area, and at select Navy pierside and harbor locations. These military readiness activities are generally consistent with those analyzed in the HSTT Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS) completed in December 2013 and are representative of training and testing that the Navy has been conducting in the HSTT Study Area for decades.

In this chapter, the Navy builds upon the purpose and need to train and test by describing the Study Area and identifying the primary mission areas under which these military readiness activities are conducted. Each warfare community, e.g., aviation, surface, submarine, expeditionary, conducts activities that contribute to the success of a primary mission area (described in Section 2.2, Primary Mission Areas). Each primary mission area requires unique skills, sensors, weapons, and technologies to accomplish the mission. For example, under the anti-submarine warfare primary mission area, surface, submarine, and aviation warfare communities each utilize different skills, sensors, and weapons to locate, track, and eliminate submarine threats. The testing community contributes to the success of anti-submarine warfare by anticipating and identifying technologies and systems that respond to the needs of the warfare communities. As each warfare community develops its basic skills and integrates them into combined units and strike groups, the problems of communication, coordination and planning, movement, and positioning of naval forces and targeting/delivery of weapons become increasingly complex. This complexity creates a need for coordinated training and testing between the fleets and systems commands.

This chapter describes the training and testing activities, which comprise the Proposed Action, necessary to meet military readiness requirements. These activities are then analyzed for their potential effects on the environment in the following chapters of this EIS/OEIS. For further details regarding specific training and testing activities, please see Appendix A (Navy Activity Descriptions). In accordance with the Marine Mammal Protection Act (MMPA), the Navy submitted to the National Marine Fisheries Service (NMFS) an application requesting authorization for the take of marine mammals incidental to training and testing activities described in this EIS/OEIS. NMFS' proposed action will be a direct outcome of responding to the Navy's request for an incidental take authorization pursuant to the MMPA.

2.1 DESCRIPTION OF THE HAWAII-SOUTHERN CALIFORNIA TRAINING AND TESTING STUDY AREA

The HSTT EIS/OEIS Study Area (Study Area) is virtually the same as analyzed in the 2013 HSTT EIS/OEIS, but has been reduced slightly along the eastern and southeastern boundaries of W-291. In 2017, the dimensions of W-291 were adjusted. Because this portion of the HSTT Study Area is defined by W-291, the Study Area boundaries also changed. The resulting reduction in Study Area size is approximately

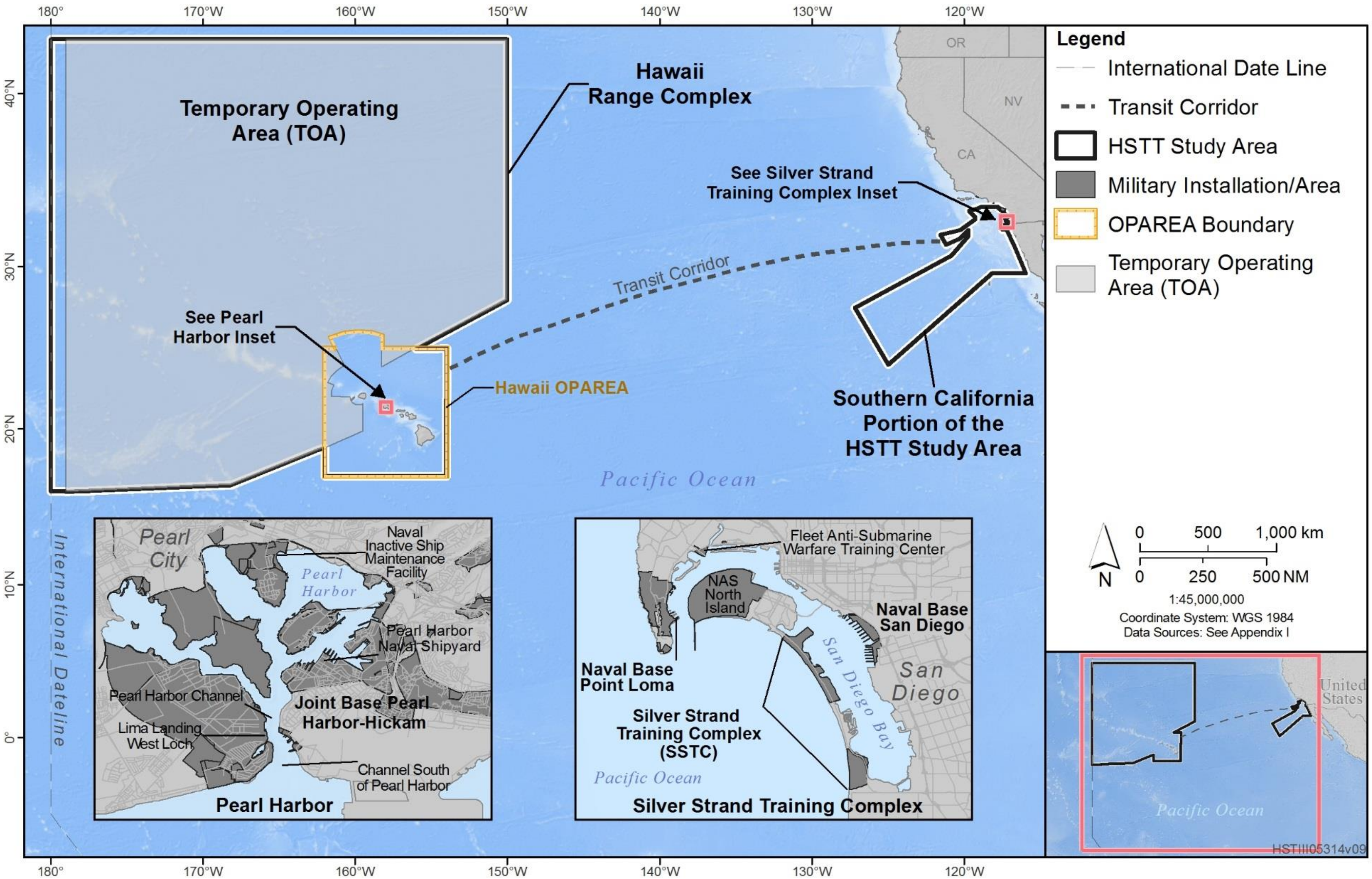

Figure 2.1-1: Hawaii-Southern California Training and Testing Study Area

Notes: HSTT = Hawaii-Southern California Training and Testing, OPAREA = Operating Area

1 percent of the total area. The Study Area is comprised of established operating and warning areas across the north-central Pacific Ocean, from the mean high tide line in Southern California west to Hawaii and the International Date Line. Because the Navy's activities would occur well within the boundaries of the Study Area, the effects of the action would remain within those same boundaries. The Study Area includes the Hawaii Range Complex, Southern California Range Complex, the Point Mugu Sea Range overlap, the Silver Strand Training Complex, ocean areas outside the bounds of existing range complexes (i.e., the transit corridor), pierside locations in Hawaii and Southern California, and San Diego Bay.

A Navy range complex consists of geographic areas that may encompass a water component (above and below the surface) and airspace, and may encompass a land component where training and testing of military platforms, tactics, munitions, explosives, and electronic warfare systems occur. Range complexes include established operating areas and special use airspace, which may be further divided to provide better control of the area for safety reasons. The terms used to describe the components of the range complexes are described below:

- **Airspace**
  - **Special Use Airspace**. Airspace of defined dimensions where activities must be confined because of their nature or where limitations may be imposed upon aircraft operations that are not part of those activities (Federal Aviation Administration Order 7400.8). Types of special use airspace most commonly found in range complexes include the following:
    - **Restricted Areas**. Airspace within which the operation of aircraft is subject to restriction. Restricted areas are established to separate activities considered to be hazardous to other aircraft, such as artillery firing or aerial gunnery munitions.
    - **Military Operations Areas**. Airspace with defined vertical and lateral limits established for the purpose of separating or segregating certain military training activities from instrument flight rules traffic and to identify visual flight rules traffic where these activities are conducted.
    - **Warning Area**. Areas of defined dimensions, extending from 3 nautical miles (NM) outward from the coast of the United States, which serve to warn non-participating aircraft of activities that may be hazardous.
  - **Air Traffic Control Assigned Airspace**. Airspace of defined vertical/lateral limits, implemented by Letter of Agreement between the user and the concerned Air Route Traffic Control Center, and assigned by Air Traffic Control, for the purpose of providing air traffic segregation between the specified activity being conducted within the assigned airspace and other instrument flight rules traffic.
- **Sea and Undersea Space**
  - **Operating Area**. An ocean area defined by geographic coordinates with defined surface and subsurface areas and associated special use airspace. Operating areas (OPAREAs) may include danger zones and restricted areas.

- **Danger Zones and Restricted Areas**. Danger zones and restricted areas are defined water areas for the purpose of prohibiting or limiting public access. Restricted areas generally provide security for government property and also provide protection to the public from the risks of damage or injury arising from the government's use of that area (33 Code of Federal Regulations [CFR] part 334).

The Study Area includes only the at-sea components of the range complexes. Land components associated with the range complexes are not included in the Study Area, and no activities on these land areas are included as part of the Proposed Action.

The Study Area and typical transit corridor between Hawaii and Southern California are depicted in Figure 2.1-1. Regional maps contained in Figures 2.1-2 through 2.1-9 are provided for additional details of the range complexes and training areas. The range complexes and components of these ranges are described in the following sections.

2.1.1 HAWAII RANGE COMPLEX

The Hawaii Range Complex is comprised of the Temporary OPAREA and the Hawaii OPAREA. The ocean areas of the Hawaii Range Complex extend from 16 degrees north latitude to 43 degrees north latitude and from 150 degrees west longitude to the International Date Line, forming an area approximately 1,700 by 1,600 NM.

2.1.1.1 The Temporary Operating Area

The largest component of the Hawaii Range Complex is the Temporary OPAREA, extending north and west from the island of Kauai and comprising over 2 million square nautical miles (NM^2) of air and sea space. The Temporary OPAREA is used for missile testing by the Pacific Missile Range Facility, but those missile tests are covered by environmental compliance documents and consultations outside of this EIS/OEIS. For this EIS/OEIS, the Temporary OPAREA is used for Navy ship transits throughout the year. In spite of the Temporary OPAREA’s size, nearly all of the training and testing activities in the Hawaii Range Complex take place within the smaller Hawaii OPAREA, which is the portion of the range complex that immediately surrounds the island chain from Hawaii to Kauai (Figure 2.1-2 through Figure 2.1-5).

2.1.1.2 The Hawaii Operating Area

The Hawaii OPAREA geographically encompasses ocean areas located around the Hawaiian Islands chain. The Hawaii OPAREA consists of 235,000 NM^2 of special use airspace and ocean areas.

2.1.1.2.1 Airspace

The Hawaii OPAREA includes over 115,000 NM^2 of combined special use airspace and air traffic controlled assigned airspace. As depicted in Figure 2.1-2, this airspace is almost entirely over the ocean and includes warning areas, air traffic control assigned airspace, and restricted areas.

Warning Areas of the Hawaii OPAREA make up more than 58,000 NM^2 of special use airspace and include the following: W-186, W-187, W-188, W-189, W-190, W-191, W-192, W-193, W-194, and W-196.

The air traffic control assigned airspace areas of the Hawaii OPAREA account for more than 57,000 NM^2 of airspace and include the following areas: Luna East, Luna Central, Luna West, Mahi, Haka, Mela South, Mela Central, Mela North, Nalu, Taro, Kaela East, Kaela West, Pele, and Pele South.

The restricted area airspace over or near land areas within the Hawaii OPAREA make up another 81 NM^2 of special use airspace and include R-3101, R-3103, and R-3107. Kaula Island is located completely within

R-3107, west-southwest of Kauai. This EIS/OEIS will include analysis of only the marine environment surrounding Kaula Island, and not potential impacts on the island itself. Impacts on the natural and cultural resources of Kaula Island were analyzed in the Hawaii Range Complex EIS/OEIS (U.S. Department of the Navy, 2008); there have been no substantial changes to that land-based activity and there is no new additional significant information.

2.1.1.2.2 Sea and Undersea Space

The Hawaii OPAREA includes the ocean areas as described above, as well as specific training areas around the islands of Kauai (Figure 2.1-3), Oahu (Figure 2.1-4), Hawaii, and Maui (Figure 2.1-5):

- Pacific Missile Range Facility (Figure 2.1-3) supports subsurface, surface, air, and space activities. It consists of 1,100 NM^2 of instrumented underwater ranges at depths between 129 feet (ft.) and 15,000 ft. The Pacific Missile Range Facility provides major range services for training; tactics development; and evaluation of air, surface, and subsurface weapons systems for the Navy, other Department of Defense (DoD) agencies, foreign military forces, and private industry. The Pacific Missile Range Facility includes the following:
    - Barking Sands Tactical Underwater Range (Figure 2.1-3) is an instrumented underwater range that provides approximately 120 NM^2 of underwater tracking of participants and targets.
    - Barking Sands Underwater Range Expansion (Figure 2.1-3) extends the Barking Sands Tactical Underwater Range to the north and provides an additional 900 NM^2 of underwater tracking capability.
    - The Shallow Water Training Range (Figure 2.1-3) is an instrumented underwater range available for shallow water tracking.
    - The Kingfisher Training Minefield Underwater (Figure 2.1-3) is a training area approximately 2 miles (mi.) off the southeast coast of Niihau that provides mine avoidance training for surface ships.
- The Fleet Operational Readiness Accuracy Check Site (Figure 2.1-4) checks range and bearing accuracy for Navy and Coast Guard ships to ensure equipment function and calibration.
- The Surface Ship Radiated Noise Measurement System (Figure 2.1-4) evaluates waterborne acoustic characteristics of Navy ships, which may provide information to determine corrective actions to reduce a ship's acoustic noise, thus reducing vulnerability to undersea warfare threats.
- The Shipboard Electronic Systems Evaluation Facility (Figure 2.1-4) evaluates ship, shore, and aircraft systems that emit or detect electronic emissions.
- Barbers Point Underwater Range (Figure 2.1-4) provides nearshore water space for mine neutralization training activities.
- Puuloa Underwater Range (Figure 2.1-4) is a 1 NM^2 area in the open ocean outside and to the west of the entrance to Pearl Harbor providing nearshore water space for Explosive Ordnance Disposal training.
- Ewa Training Minefield (Figure 2.1-4) is an ocean area extending from Ewa Beach approximately 2 NM toward Barbers Point, and out to sea approximately 4 NM. This restricted area provides water space for surface ship mine avoidance training.

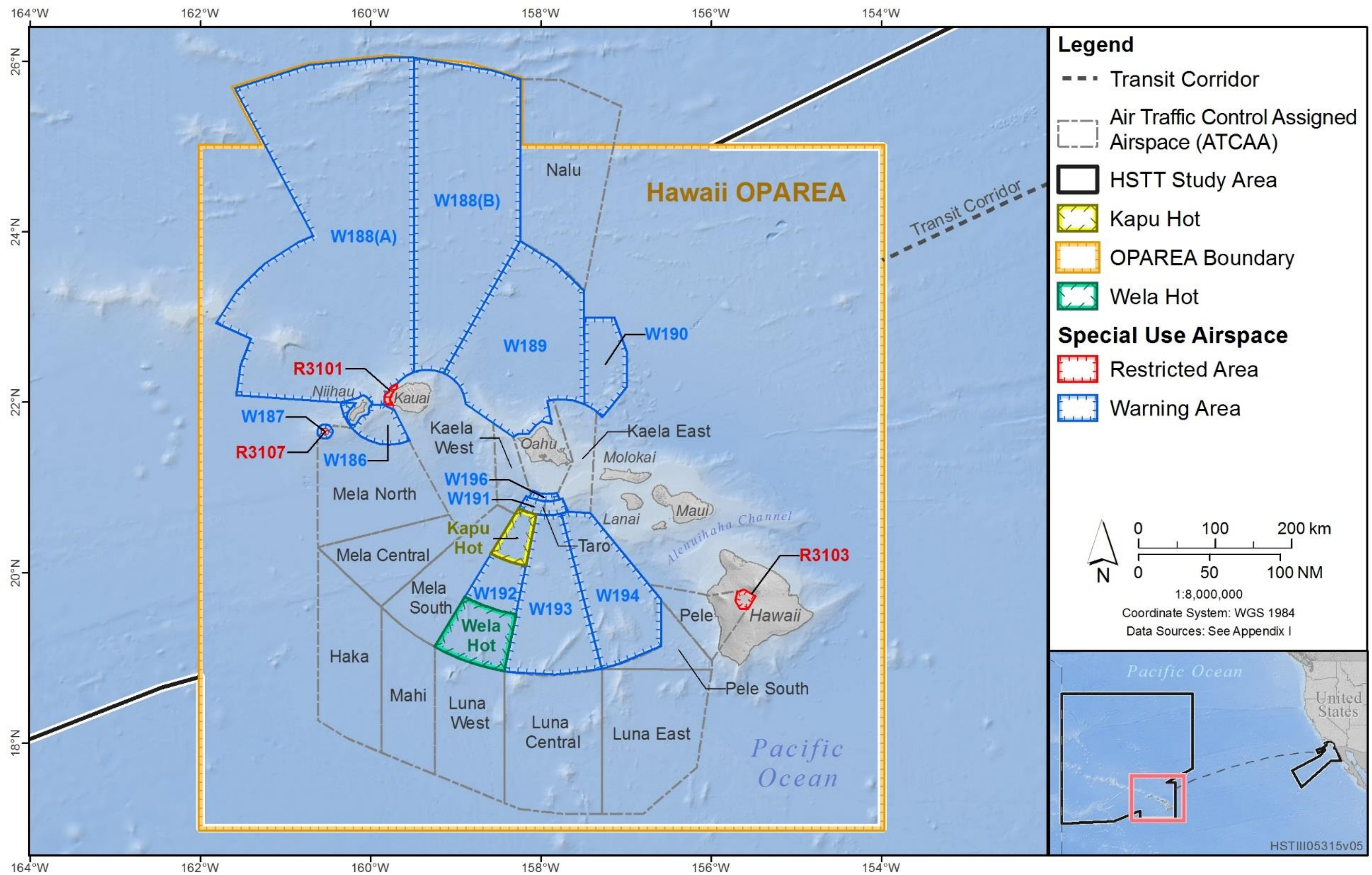

Figure 2.1-2: Hawaii Operating Area

Notes: HSTT = Hawaii-Southern California Training and Testing, OPAREA = Operating Area

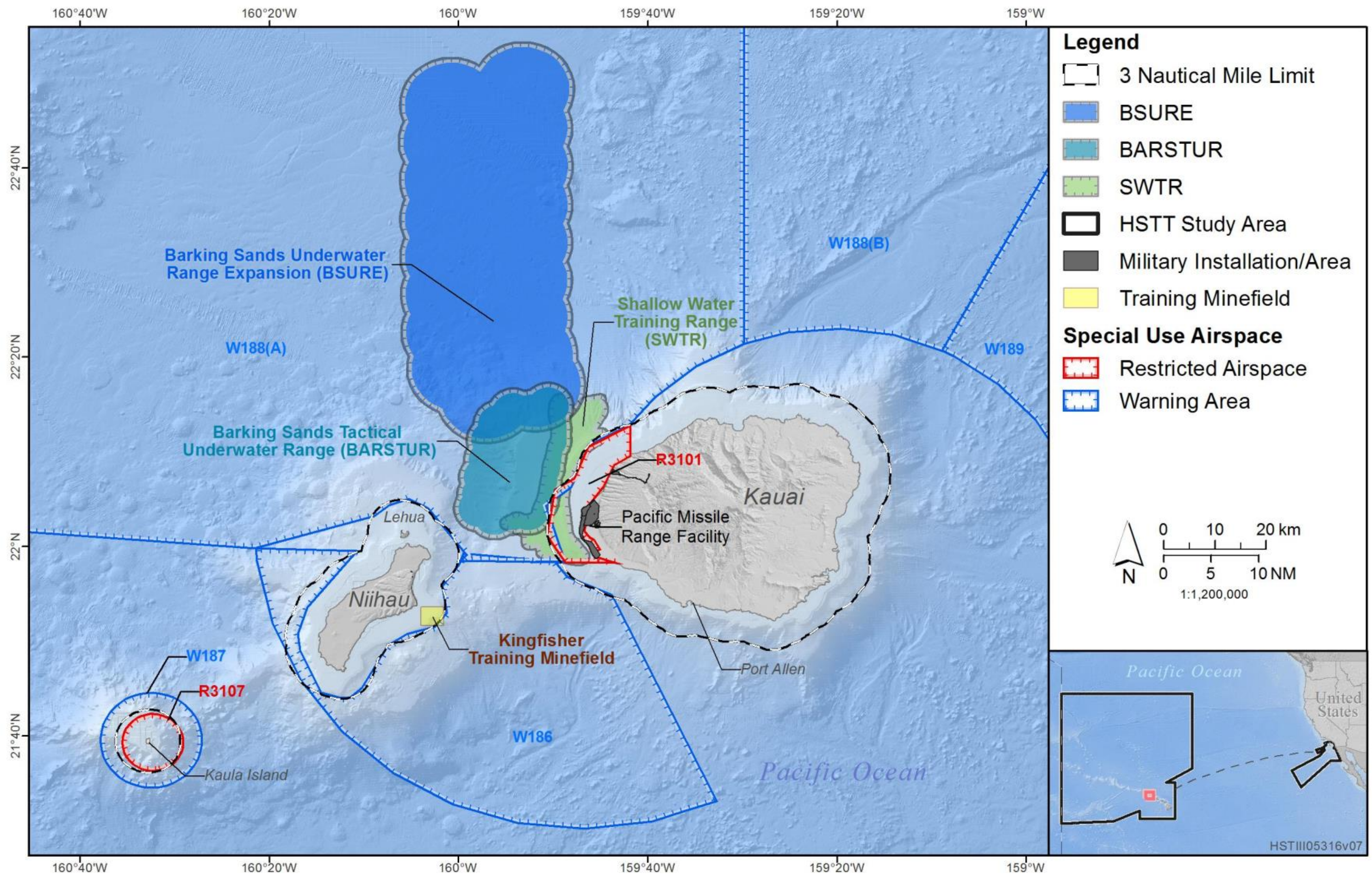

Figure 2.1-3: Navy Training and Testing Areas Around Kauai

Note: HSTT = Hawaii-Southern California Training and Testing

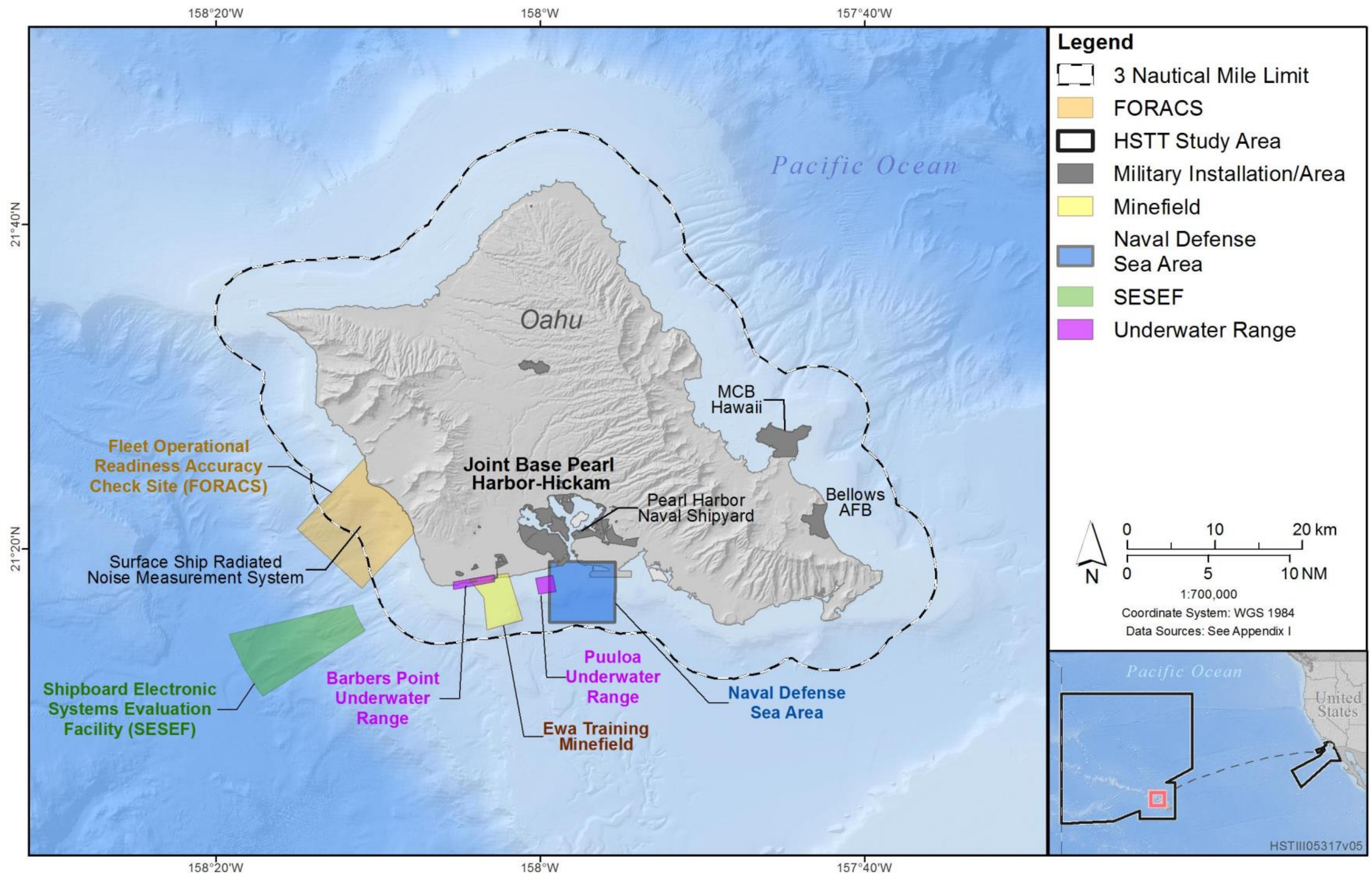

Figure 2.1-4: Navy Training and Testing Areas Around Oahu

Notes: HSTT = Hawaii-Southern California Training and Testing, MCB = Marine Corps Base, AFB = Air Force Base

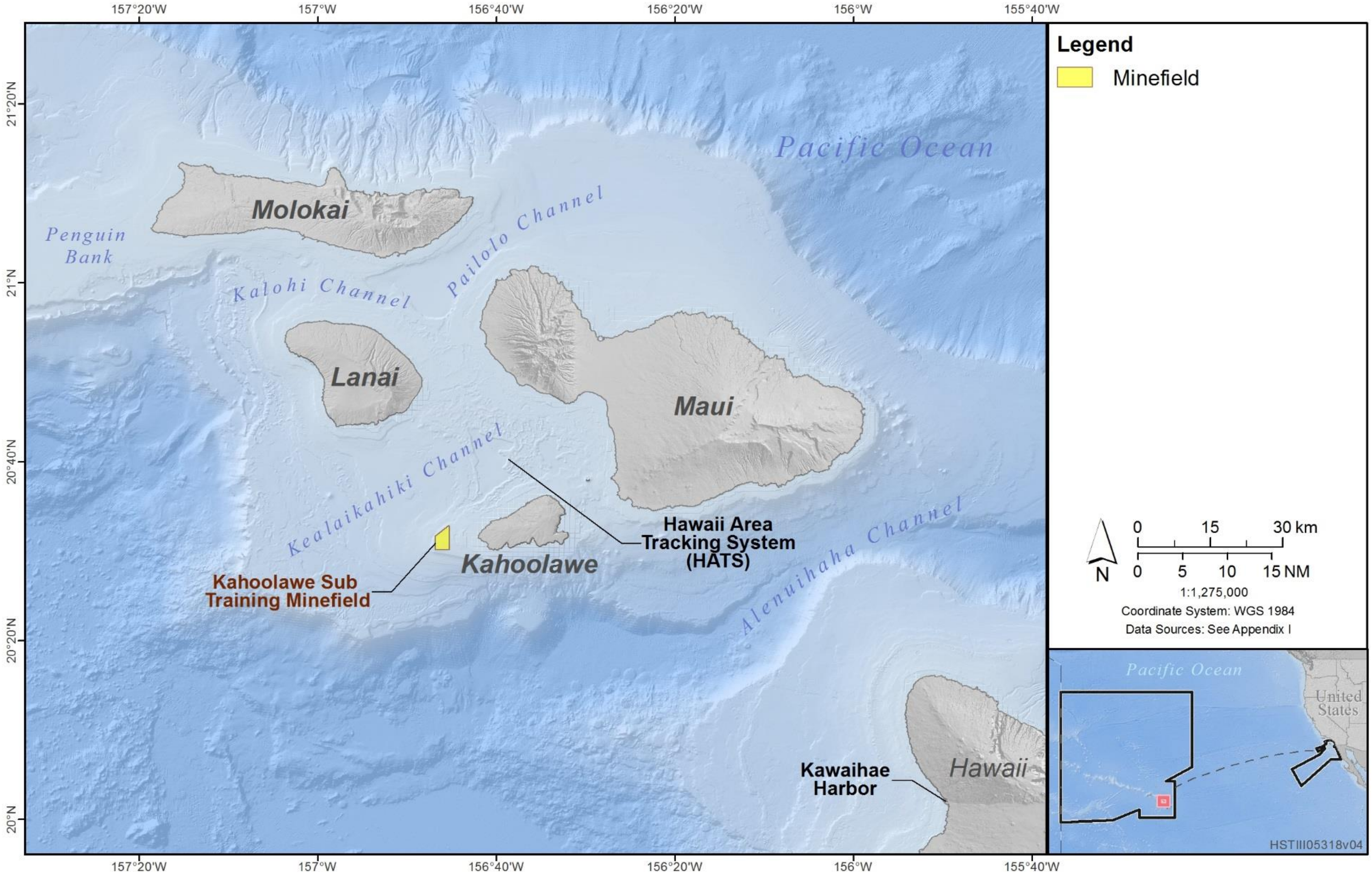

Figure 2.1-5: Navy Training and Testing Areas Around Maui

- Hawaii Area Tracking System (Figure 2.1-5) is an ocean area approximately 9 NM off the southwest coast of the island of Maui, used for submarine training.
- Kahoolawe Sub Training Minefield (Figure 2.1-5) is an ocean area approximately 3 NM off the west coast of the island of Kahoolawe, used by submarines for mine avoidance training.

2.1.2 Southern California Portion of the HSTT Study Area

The Southern California portion of the HSTT Study Area (Figure 2.1-6) is comprised of the Southern California Range Complex, Point Mugu Sea Range Overlap, and Silver Strand Training Complex.

2.1.2.1 Southern California Range Complex

The Southern California Range Complex is situated between Dana Point and San Diego, and extends more than 600 NM southwest into the Pacific Ocean (Figures 2.1-6 through 2.1-9). Despite its size, most activities occur within the eastern portion of the range complex, nearer to shore and established range capabilities. The two primary components of the Southern California Range Complex are the ocean OPAREAs and the special use airspace. These components encompass 120,000 NM^2 of sea space, 113,000 NM^2 of special use airspace, and over 56 square miles ($mi.^2$) of land area on San Clemente Island and the Silver Strand Training Complex.

2.1.2.1.1 Airspace

Most of the special use airspace in the Southern California Range Complex is defined by Warning Area 291 (W-291) (Figure 2.1-6, Figure 2.1-7, and Figure 2.1-8). Warning Area 291 extends vertically from the ocean surface to 80,000 ft. above mean sea level and encompasses 113,000 NM^2 of airspace. Airspace within or adjacent to W-291 includes the following:

- Two Helicopter Offshore Training Areas (Figure 2.1-6) located off the coast of San Diego, which extend from the surface to 1,000 ft. above mean sea level.
- Tactical Maneuvering Areas (Figure 2.1-6) extend from 5,000 ft. to 40,000 ft. above mean sea level and provide airspace for air combat maneuvering, air intercept control aerobatics, and air-to-air gunnery.
- Fleet Training Area Hot (Figure 2.1-6) extends from the ocean bottom to 80,000 ft. above mean sea level and includes airspace that is used for hazardous operations, primarily surface-to-surface, surface-to-air, and air-to-air munitions.
- Missile Ranges 1 East and 1 West (Figure 2.1-6) extend from the ocean bottom to 80,000 ft. above mean sea level and allow rocket and missile firing activities, anti-submarine warfare, carrier and submarine operations, Fleet training, and surface and air gunnery.
- Encinitas Naval Electronic Test Area (Figure 2.1-6) extends from the ocean bottom up to 700 ft. above mean sea level. Fleet training and testing occurs here.
- Western San Clemente OPAREA (Figure 2.1-6) is a special use airspace that extends from the surface to 5,000 ft. above mean sea level.

2.1.2.1.2 Sea and Undersea Space

The Southern California Range Complex includes approximately 120,000 NM^2 of sea and undersea space, largely defined as that ocean area underlying the Southern California special use airspace described above. The Southern California Range Complex also extends beyond this airspace to include the airspace, surface, and subsurface area from the northeastern border of W-291 to the coast of San Diego County, the Silver Strand Training Complex, and San Diego Bay. Specific training and testing areas within the Southern California Range Complex (Figure 2.1-6, Figure 2.1-8, and Figure 2.1-9) include:

- Laser Training Ranges (Figure 2.1-8) are established to conduct over-the-water laser training and testing of the laser-guided Hellfire missile.
- Mine Training Ranges (Figure 2.1-8) are used for training of aircrews in offensive mine laying by delivery of non-explosive mine shapes from aircraft.
- Minefields (Figure 2.1-6, Figure 2.1-8, and Figure 2.1-9) provide mine detection training capabilities.
- San Clemente Island Underwater Range (Figure 2.1-8) has passive hydrophone arrays mounted on the seafloor and is used for antisubmarine warfare training and testing of undersea systems.
- Southern California Offshore Anti-submarine Warfare Range (Figure 2.1-8) is an underwater tracking range with the capability to provide three-dimensional underwater tracking of submarines, practice weapons, and targets.
- Shallow Water Training Range (Figure 2.1-6 and Figure 2.1-8) is an extension into shallow water of the deeper water tracking range.
- Shore Bombardment Area (Figure 2.1-6 and Figure 2.1-8) is the only eastern Pacific Fleet range that supports naval surface fire support training (only the water area surrounding the land portion of the range is included for analysis in this EIS/OEIS).
- Special Warfare Training Areas (Figure 2.1-9) support expeditionary and amphibious warfare training.
- Training Areas and Ranges (Figure 2.1-9) are littoral operating areas that support demolition, over-the-beach, and tactical ingress and egress training for Navy personnel.
- Camp Pendleton Amphibious Assault Area (Figure 2.1-6) provides an amphibious assault training environment.

2.1.2.2 Point Mugu Sea Range Overlap

A small portion (approximately 1,000 NM^2) of the Point Mugu Sea Range (hereafter referred to as the "Point Mugu Sea Range overlap") is included in the Study Area (Figure 2.1-7). Only that part of the Point Mugu Sea Range is used by the Navy for anti-submarine warfare training; this training uses sonar, is conducted in the course of major training exercises, and is analyzed in this document. Other non-dependent and non-connected activities at the Point Mugu Sea Range, including San Nicolas Island, are addressed in separate National Environmental Policy Act (NEPA) documents.

2.1.2.3 Silver Strand Training Complex

The Silver Strand Training Complex is an integrated set of training areas located on and adjacent to the Silver Strand, a narrow, sandy isthmus separating the San Diego Bay from the Pacific Ocean. It is divided into two non-contiguous areas: Silver Strand Training Complex-North and Silver Strand Training Complex-South (Figure 2.1-10). The Silver Strand Training Complex-North includes 10 oceanside boat training lanes (numbered as Boat Lanes 1-10), ocean anchorage areas (numbered 101–178), bayside water training areas (Alpha through Hotel), and the Lilly Ann drop zone. The boat training lanes are each 500 yards (yd.) wide stretching 4,000 yd. seaward and forming a 5,000 yd. long contiguous training area.

The Silver Strand Training Complex-South includes four oceanside boat training lanes (numbered as Boat Lanes 11-14) and the training area Kilo.

The anchorages lie offshore of Coronado in the Pacific Ocean and overlap a portion of Boat Lanes 1–10. The anchorages are each 654 yd. in diameter and are grouped together in an area located primarily due west of Silver Strand Training Complex-North, east of Zuniga Jetty and the restricted areas on approach to the San Diego Bay entrance.

2.1.3 Ocean Areas Outside the Bounds of Existing Range Complexes (Transit Corridor)

In addition to the range complexes that are part of the Study Area, a transit corridor outside the boundaries of the range complexes will also be included as part of the Study Area in the analysis. Although not part of any defined range complex, this transit corridor is important to the Navy in that it provides adequate air, sea, and undersea space in which vessels and aircraft conduct training and some sonar maintenance and testing while en route between Southern California and Hawaii.

The transit corridor, notionally defined by the great circle route (e.g., shortest distance) from San Diego to the center of the Hawaii Range Complex, as depicted in Figure 2.1-1, is generally used by ships transiting between the Southern California Range Complex and Hawaii Range Complex. While in transit, ships and aircraft would, at times, conduct basic and routine unit-level activities such as gunnery, bombing, and sonar training and maintenance.

2.1.4 Pierside Locations and San Diego Bay

The Study Area includes select pierside locations where Navy surface ship and submarine sonar maintenance testing occur. For purposes of this EIS/OEIS, pierside locations include channels and routes to and from Navy ports, and facilities associated with Navy ports and shipyards. These locations in the Study Area are located at Navy ports and naval shipyards in San Diego Bay, California and Pearl Harbor, Hawaii (Figure 2.1-11). In addition, some training and testing activities occur throughout San Diego Bay.

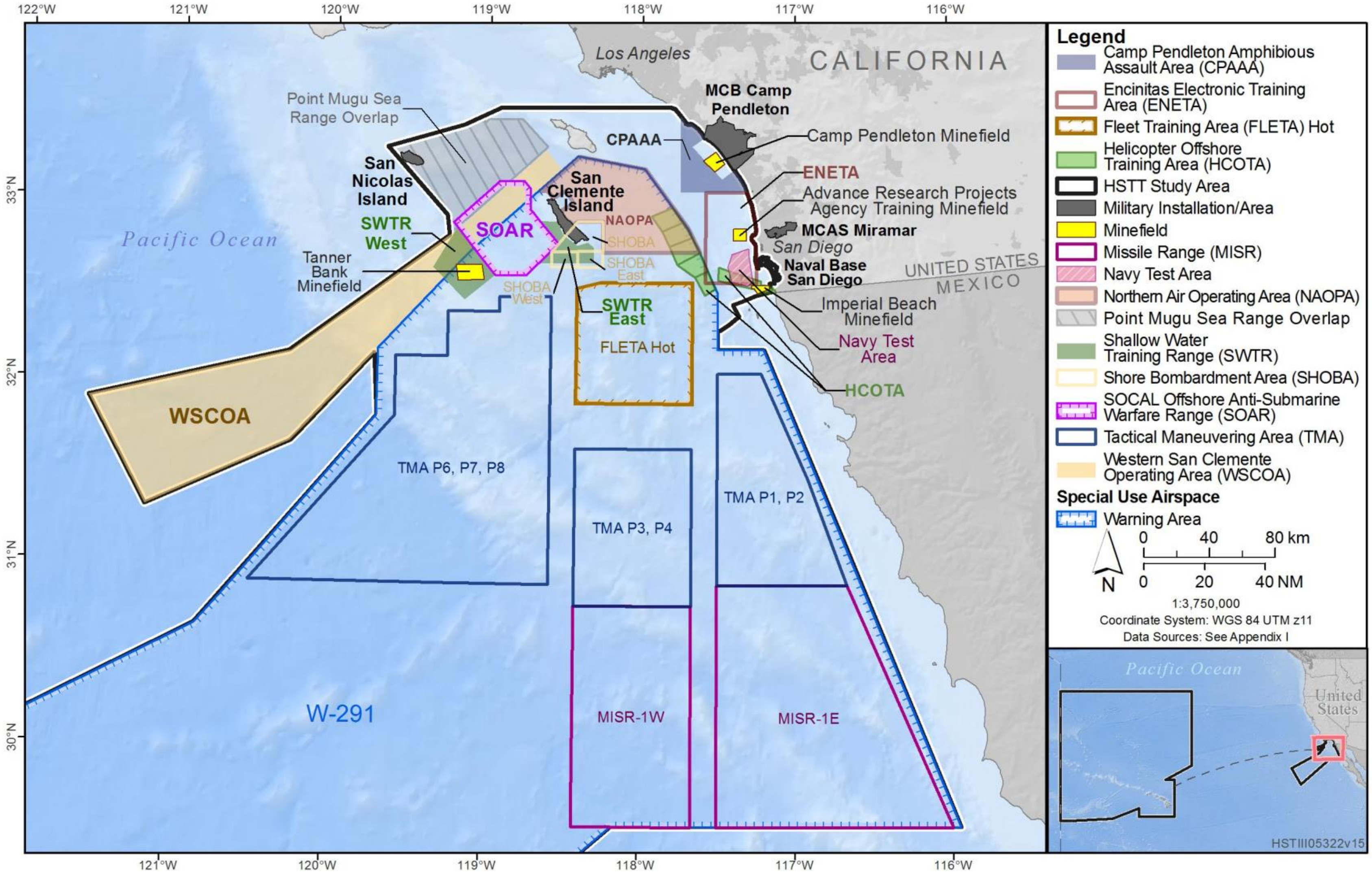

Figure 2.1-6: Southern California Portion of the HSTT Study Area

Notes: HSTT = Hawaii-Southern California Training and Testing, MCB = Marine Corps Base, MCAS = Marine Corps Air Station

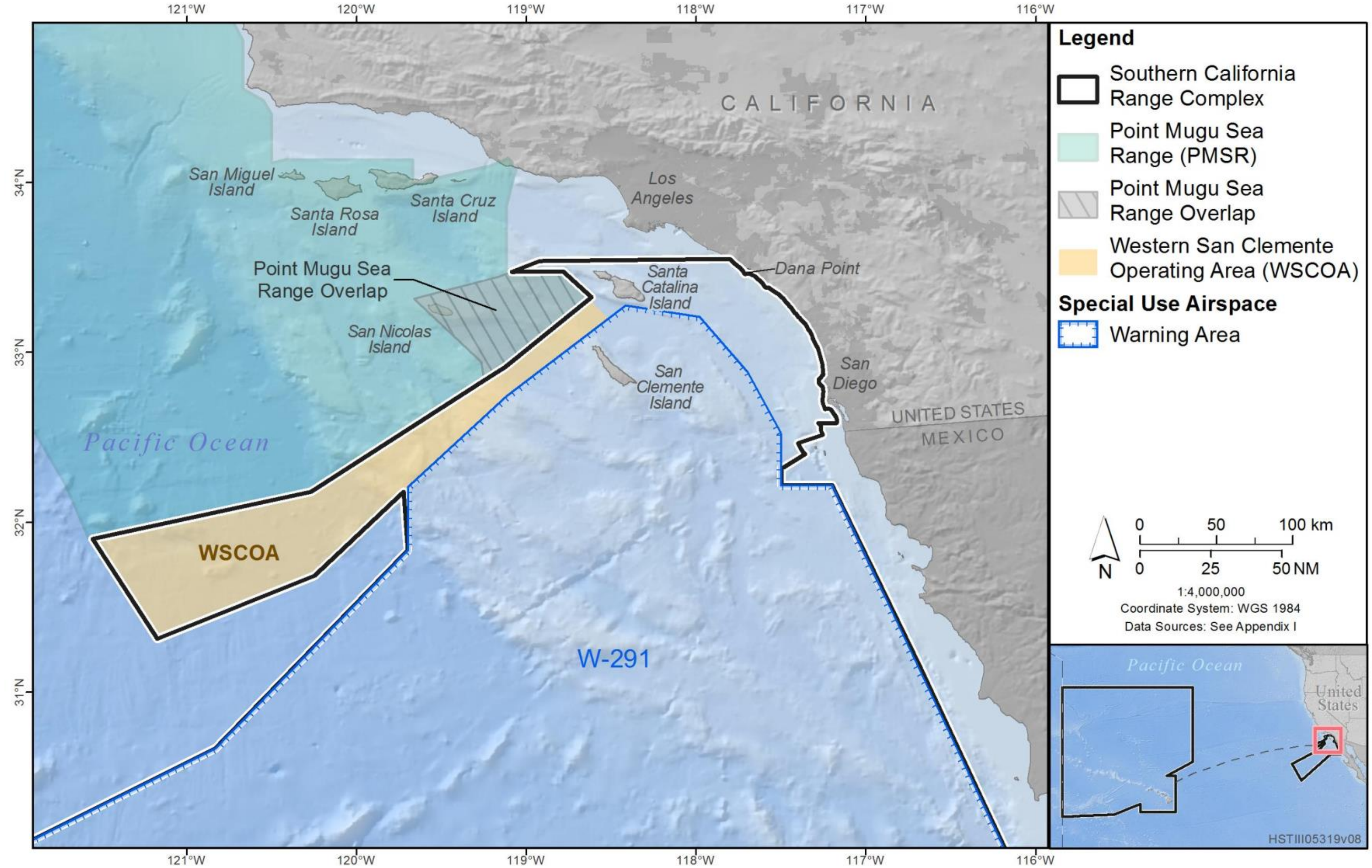

Figure 2.1-7: Southern California Range Complex

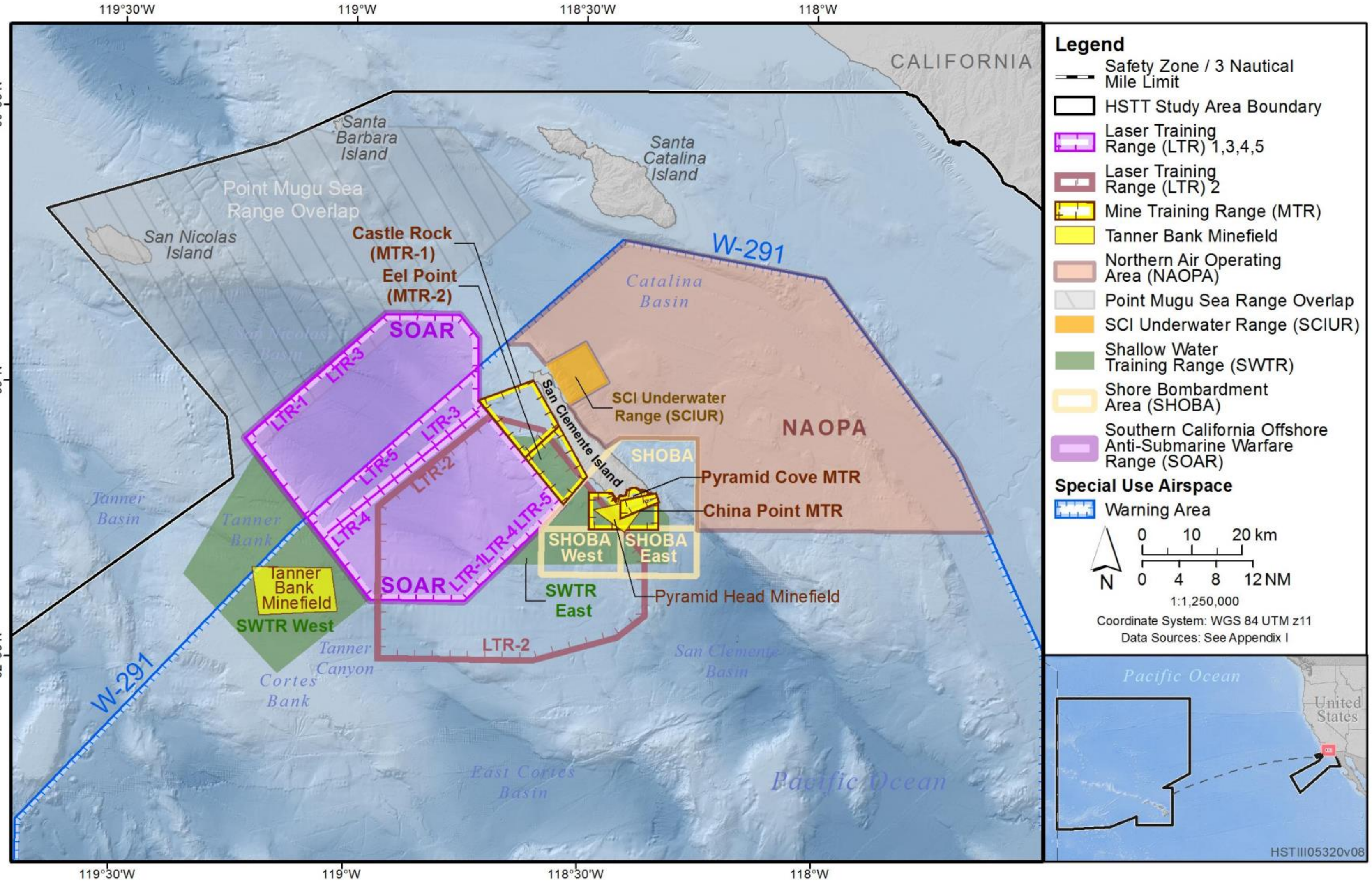

Figure 2.1-8: San Clemente Island Offshore Training and Testing Areas

Notes: HSTT = Hawaii-Southern California Training and Testing, SCI = San Clemente Island

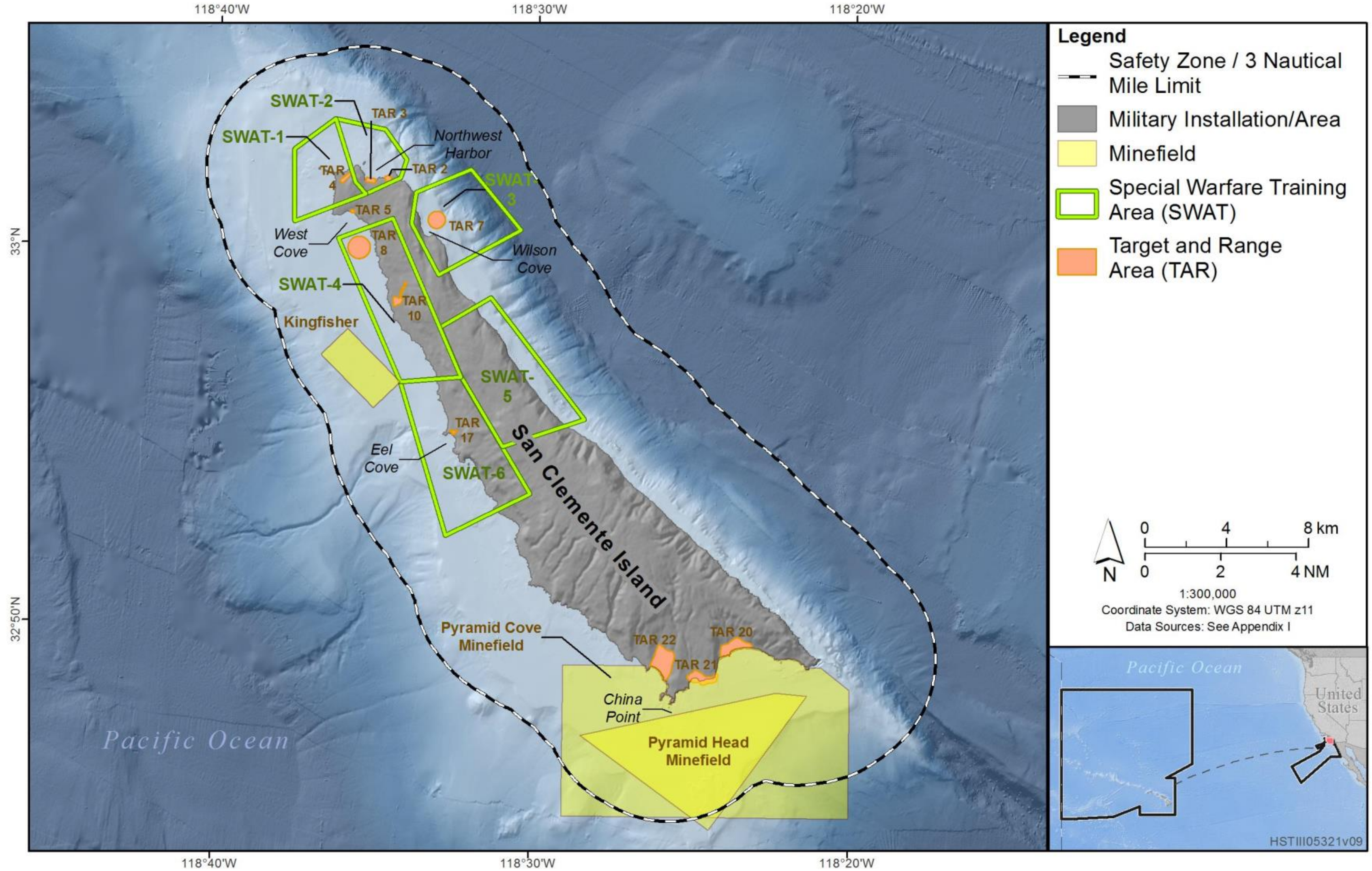

Figure 2.1-9: San Clemente Island Nearshore Training and Testing Areas

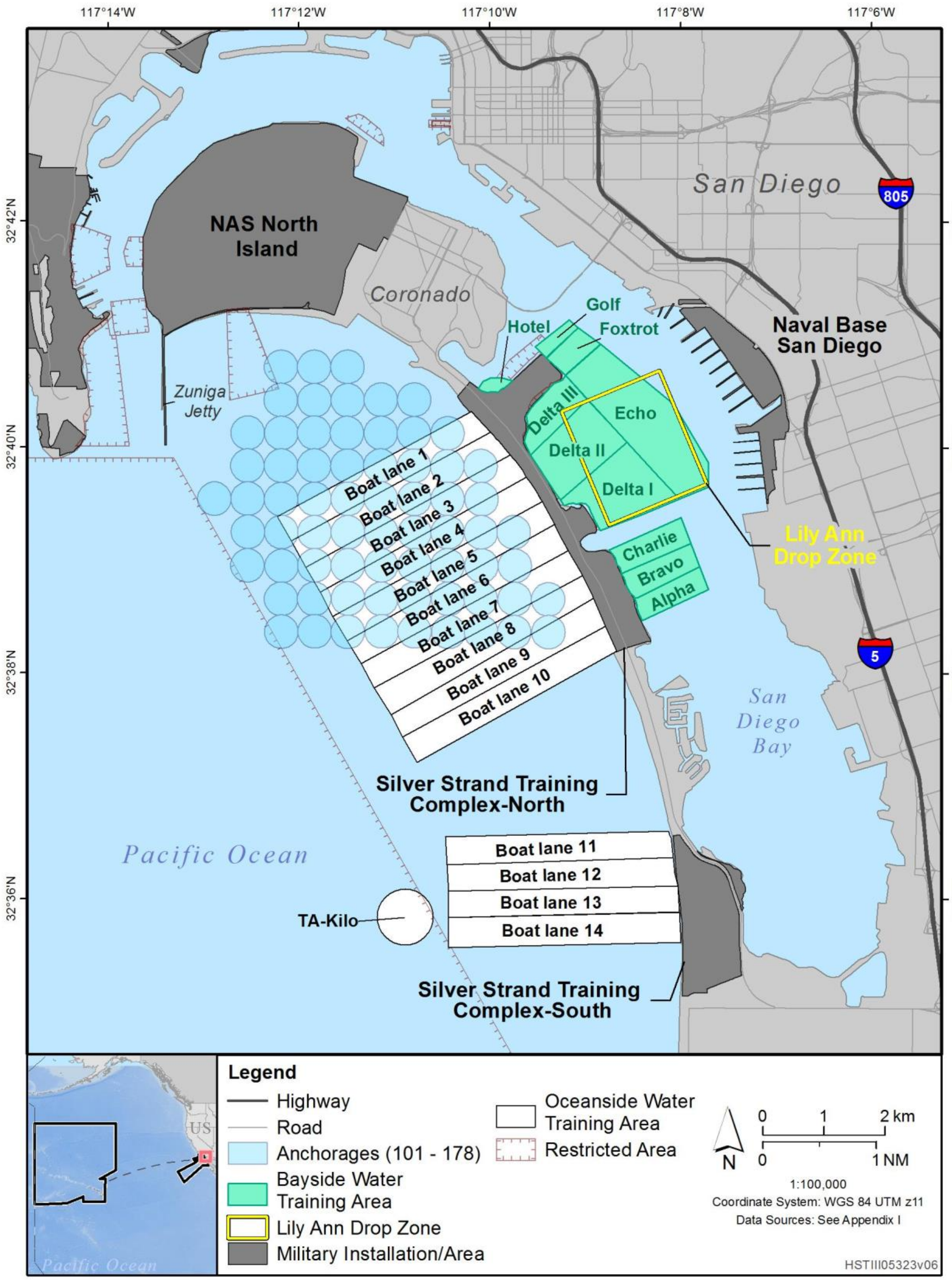

Figure 2.1-10: Silver Strand Training Complex

Notes: NAS = Naval Air Station, TA = Training Area

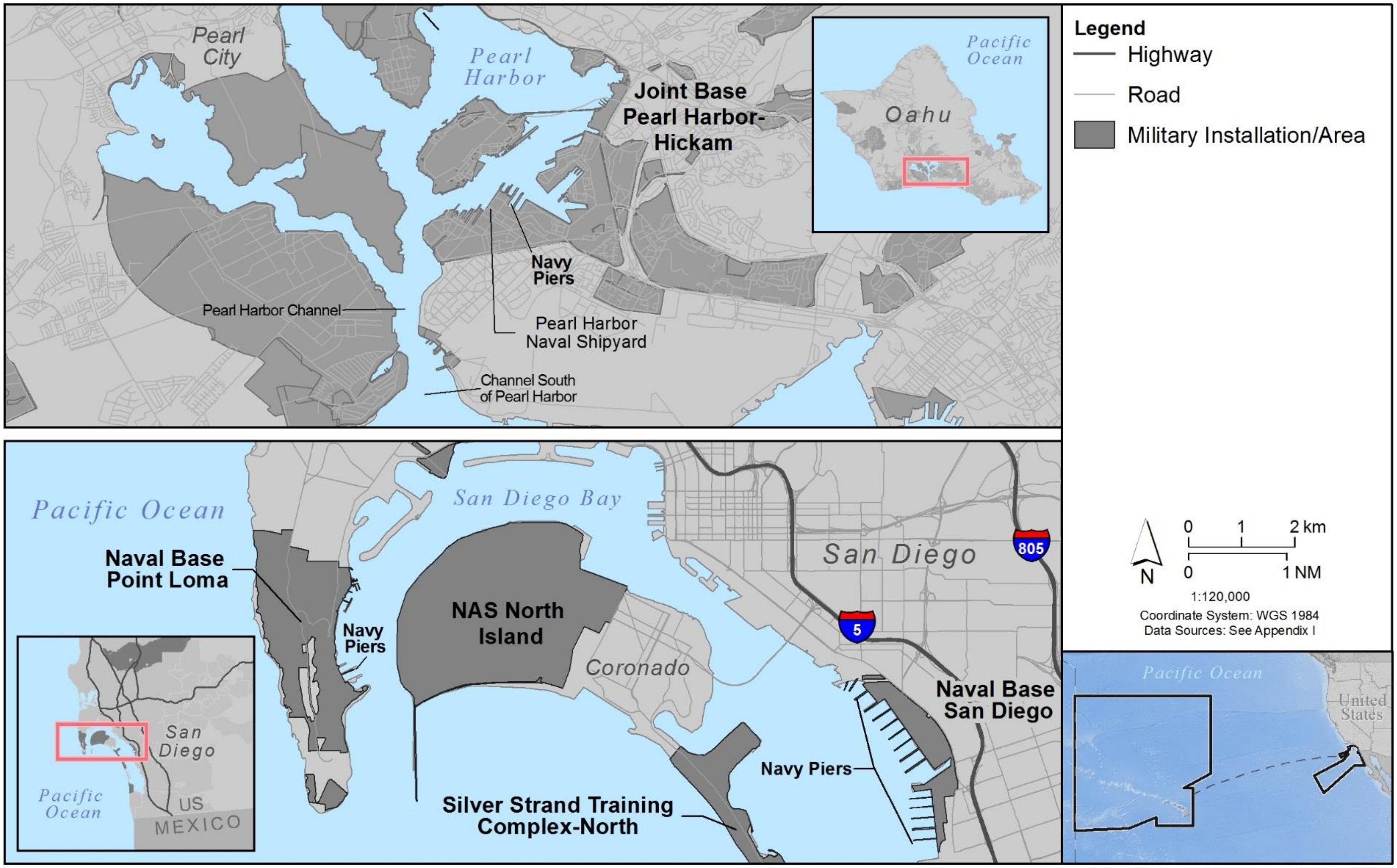

Figure 2.1-11: Navy Piers and Shipyards in Pearl Harbor and San Diego Bay

Note: NAS = Naval Air Station

2.2 Primary Mission Areas

The Navy categorizes its activities into functional warfare areas called primary mission areas. These activities generally fall into the following seven primary mission areas:

- air warfare
- amphibious warfare
- anti-submarine warfare
- electronic warfare
- expeditionary warfare
- mine warfare
- surface warfare

Most training activities addressed in this EIS/OEIS are categorized under one of these primary mission areas; activities that do not fall within one of these areas are listed as "other activities." Each warfare community (aviation, surface, submarine, and expeditionary) may train in some or all of these primary mission areas. The research and acquisition community also categorizes most, but not all, of its testing activities under these primary mission areas. A description of the sonar, munitions, targets, systems and other material used during training and testing activities within these primary mission areas is provided in Appendix A (Navy Activity Descriptions).

2.2.1 Air Warfare

The mission of air warfare is to destroy or reduce enemy air and missile threats (including unmanned airborne threats) and serves two purposes: to protect U.S. forces from attacks from the air and to gain air superiority. Air warfare provides U.S. forces with adequate attack warnings, while denying hostile forces the ability to gather intelligence about U.S. forces.

Aircraft conduct air warfare through radar search, detection, identification, and engagement of airborne threats. Surface ships conduct air warfare through an array of modern anti-aircraft weapon systems such as aircraft detecting radar, naval guns linked to radar-directed fire-control systems, surface-to-air missile systems, and radar-controlled guns for close-in point defense.

Testing of air warfare systems is required to ensure the equipment is fully functional under the conditions in which it will be used. Tests may be conducted on radar and other early-warning detection and tracking systems, new guns or gun rounds, and missiles. Testing of these systems may be conducted on new ships and aircraft, and on existing ships and aircraft following maintenance, repair, or modification. For some systems, tests are conducted periodically to assess operability. Additionally, tests may be conducted in support of scientific research to assess new and emerging technologies.

2.2.2 Amphibious Warfare

The mission of amphibious warfare is to project military power from the sea to the shore (i.e., attack a threat on land by a military force embarked on ships) through the use of naval firepower and expeditionary landing forces. Amphibious warfare operations include small unit reconnaissance or raid missions to large-scale amphibious exercises involving multiple ships and aircraft combined into a strike group.

Amphibious warfare training ranges from individual, crew, and small unit events to large task force exercises. Individual and crew training include amphibious vehicles and naval gunfire support training. Such training includes shore assaults, boat raids, airfield or port seizures, and reconnaissance. Large-scale amphibious exercises involve ship-to-shore maneuver, naval fire support, such as shore bombardment, and air strike and attacks on targets that are in close proximity to friendly forces.

Testing of guns, munitions, aircraft, ships, and amphibious vessels and vehicles used in amphibious warfare are often integrated into training activities and, in most cases, the systems are used in the same manner in which they are used for fleet training activities. Amphibious warfare tests, when integrated with training activities or conducted separately as full operational evaluations on existing amphibious vessels and vehicles following maintenance, repair, or modernization, may be conducted independently or in conjunction with other amphibious ship and aircraft activities. Testing is performed to ensure effective ship-to-shore coordination and transport of personnel, equipment, and supplies. Tests may also be conducted periodically on other systems, vessels, and aircraft intended for amphibious operations to assess operability and to investigate efficacy of new technologies.

2.2.3 Anti-Submarine Warfare

The mission of anti-submarine warfare is to locate, neutralize, and defeat hostile submarine forces that threaten Navy surface forces. Anti-submarine warfare is based on the principle that surveillance and attack aircraft, ships, and submarines all search for hostile submarines. These forces operate together or independently to gain early warning and detection, and to localize, track, target, and attack submarine threats.

Anti-submarine warfare training addresses basic skills such as detection and classification of submarines, as well as evaluating sounds to distinguish between enemy submarines and friendly submarines, ships, and marine life. More advanced training integrates the full spectrum of anti-submarine warfare from detecting and tracking a submarine to attacking a target using either exercise torpedoes (i.e., torpedoes that do not contain a warhead) or simulated weapons. These integrated anti-submarine warfare training exercises are conducted in coordinated, at-sea training events involving submarines, ships, and aircraft.

Testing of anti-submarine warfare systems is conducted to develop new technologies and assess weapon performance and operability with new systems and platforms, such as unmanned systems. Testing uses ships, submarines, and aircraft to demonstrate capabilities of torpedoes, missiles, countermeasure systems, and underwater surveillance and communications systems. Tests may be conducted as part of a large-scale fleet training event involving submarines, ships, fixed-wing aircraft, and helicopters. These integrated training events offer opportunities to conduct research and acquisition activities and to train aircrew in the use of new or newly enhanced systems during a large-scale, complex exercise.

2.2.4 Electronic Warfare

The mission of electronic warfare is to degrade the enemy's ability to use electronic systems, such as communication systems and radar, and to confuse or deny them the ability to defend their forces and assets. Electronic warfare is also used to detect enemy threats and counter their attempts to degrade the electronic capabilities of the Navy.

Typical electronic warfare activities include threat avoidance training, signals analysis for intelligence purposes, and use of airborne and surface electronic jamming devices (that block or interfere with other devices) to defeat tracking, navigation, and communications systems.

Testing of electronic warfare systems is conducted to improve the capabilities of systems and ensure compatibility with new systems. Testing involves the use of aircraft, surface ships, and submarine crews to evaluate the effectiveness of electronic systems. Similar to training activities, typical electronic warfare testing activities include the use of airborne and surface electronic jamming devices (including testing chaff and flares, see Appendix A, Navy Activity Descriptions, for a description of these devices) to defeat tracking and communications systems. Chaff tests evaluate newly developed or enhanced chaff, chaff dispensing equipment, or modified aircraft systems' use against chaff deployment. Flare tests evaluate deployment performance and crew competency with newly developed or enhanced flares, flare dispensing equipment, or modified aircraft systems' use against flare deployment.

2.2.5 Expeditionary Warfare

The mission of expeditionary warfare is to provide security and surveillance in the littoral (at the shoreline), riparian (along a river), or coastal environments. Expeditionary warfare is wide ranging and includes defense of harbors, operation of remotely operated vehicles, defense against swimmers, and boarding/seizure operations.

Expeditionary warfare training activities include underwater construction team training, dive and salvage operations, and insertion/extraction via air, surface, and subsurface platforms.

2.2.6 Mine Warfare

The mission of mine warfare is to detect, classify, and avoid or neutralize (disable) mines to protect Navy ships and submarines and to maintain free access to ports and shipping lanes. Mine warfare also includes offensive mine laying to gain control of or deny the enemy access to sea space. Naval mines can be laid by ships, submarines, or aircraft.

Mine warfare neutralization training includes exercises in which ships, aircraft, submarines, underwater vehicles, unmanned vehicles, or marine mammal detection systems search for mine shapes. Personnel train to destroy or disable mines by attaching underwater explosives to or near the mine or using remotely operated vehicles to destroy the mine.

Testing and development of mine warfare systems is conducted to improve sonar, laser, and magnetic detectors intended to hunt, locate, and record the positions of mines for avoidance or subsequent neutralization. Mine warfare testing and development falls into two primary categories: mine detection and classification, and mine countermeasure and neutralization. Mine detection and classification testing involves the use of air, surface, and subsurface vessels and uses sonar, including towed and side-scan sonar, and unmanned vehicles to locate and identify objects underwater. Mine detection and classification systems are sometimes used in conjunction with a mine neutralization system. Mine countermeasure and neutralization testing includes the use of air, surface, and subsurface units to evaluate the effectiveness of tracking devices and countermeasure and neutralization systems to neutralize mine threats. Most neutralization tests use mine shapes, or non-explosive practice mines, to evaluate a new or enhanced capability. For example, during a mine neutralization test, a previously located mine is destroyed or rendered nonfunctional using a helicopter or manned/unmanned surface vehicle based system that may involve the deployment of a towed neutralization system.

A small percentage of mine warfare tests require the use of high-explosive mines to evaluate and confirm the ability of the system to neutralize a high-explosive mine under operational conditions. The majority of mine warfare systems are deployed by ships, helicopters, and unmanned vehicles. Tests may also be conducted in support of scientific research to support these new technologies.

2.2.7 Surface Warfare

The mission of surface warfare is to obtain control of sea space from which naval forces may operate, and entails offensive action against other surface and subsurface targets while also defending against enemy forces. In surface warfare, aircraft use guns, air-launched cruise missiles, or other precision-guided munitions; ships employ torpedoes, naval guns, and surface-to-surface missiles; and submarines attack surface ships using torpedoes or submarine-launched, anti-ship cruise missiles.

Surface warfare training includes surface-to-surface gunnery and missile exercises, air-to-surface gunnery and missile exercises, and submarine missile or torpedo launch events, and other munitions against surface targets.

Testing of weapons used in surface warfare is conducted to develop new technologies and to assess weapon performance and operability with new systems and platforms, such as unmanned systems. Tests include various air-to-surface guns and missiles, surface-to-surface guns and missiles, and bombing tests. Testing events may be integrated into training activities to test aircraft or aircraft systems in the delivery of munitions on a surface target. In most cases the tested systems are used in the same manner in which they are used for fleet training activities.

2.3 Proposed Activities

The Navy has been conducting military readiness activities in the Study Area for decades. The tempo and types of training and testing activities have fluctuated because of the introduction of new technologies, the evolving nature of international events, advances in warfighting doctrine and procedures, and changes in force structure (organization of ships, weapons, and personnel). Such developments influence the frequency, duration, intensity, and location of required training and testing activities. This EIS/OEIS (Phase III) reflects the most up to date compilation of training and testing activities deemed necessary to accomplish military readiness requirements. The types and numbers of activities included in the Proposed Action accounts for fluctuations in training and testing in order to meet evolving or emergent military readiness requirements. For the purposes of this EIS/OEIS, the term “ship” is inclusive of surface ships and surfaced submarines. The term “vessel” is inclusive of ships and small boats (e.g., rigid-hull inflatable boats). In the following sections, the proposed training and testing activities are detailed.

2.3.1 Proposed Training Activities

A major training exercise is comprised of several "unit-level" range exercises conducted by several units operating together while commanded and controlled by a single commander. These exercises typically employ an exercise scenario developed to train and evaluate the strike group in naval tactical tasks. In a major training exercise, most of the operations and activities being directed and coordinated by the strike group commander are identical in nature to the operations conducted during individual, crew, and smaller unit-level training events. In a major training exercise, however, these disparate training tasks are conducted in concert, rather than in isolation. Some integrated or coordinated anti-submarine warfare exercises are similar in that they are comprised of several unit-level exercises but are generally on a smaller scale than a major training exercise, are shorter in duration, use fewer assets, and use fewer hours of hull-mounted sonar per exercise. These coordinated exercises are conducted under anti-submarine warfare. Three key factors used to identify and group the exercises are the scale of the exercise, duration of the exercise, and amount of hull-mounted sonar hours modeled/used for the exercise.

Table 2.3-1 provides the differences between major training exercises and smaller integrated/coordinated anti-submarine exercises based on scale, duration, and sonar hours for the purposes of exercise reporting requirements.

The training activities proposed by the Navy are described in Table 2.3-2, which includes the activity name and a short description of the activity. Appendix A (Navy Activity Descriptions) has more detailed descriptions of the activities.

Table 2.3-1: Major Anti-Submarine Warfare Training Exercises and Integrated/Coordinated Training

	Exercise Group	*Description*	*Scale*	*Duration*	*Location*	*Exercise Examples*	*Modeled Hull-mounted Sonar per Exercise*
Major Training Exercises	Large Integrated ASW	Larger-scale, longer duration integrated ASW exercises	Greater than 6 surface ASW units (up to 30 with the largest exercises), 2 or more submarines, multiple ASW aircraft	Generally greater than 10 days	SOCAL PMSR[1] HRC	RIMPAC, COMPTUEX	>500 hours
	Medium Integrated ASW	Medium-scale, medium duration integrated ASW exercises	Approximately 3–8 surface ASW units, at least 1 submarine, multiple ASW aircraft	Generally 4–10 days	SOCAL PMSR[1] HRC	FLEETEX/ SUSTEX, USWEX	100–500 hours
Integrated/Coordinated Training	Small Integrated ASW	Small-scale, short duration integrated ASW exercises	Approximately 3–6 surface ASW units, 2 dedicated submarines, 2–6 ASW aircraft	Generally less than 5 days	SOCAL HRC	SWATT, NUWTAC	50–100 hours
	Medium Coordinated ASW	Medium-scale, medium duration, coordinated ASW exercises	Approximately 2–4 surface ASW units, possibly a submarine, 2–5 ASW aircraft	Generally 3–10 days	SOCAL HRC	SCC	Less than 100 hours
	Small Coordinated ASW	Small-scale, short duration, coordinated ASW exercises	Approximately 2–4 surface ASW units, possibly a submarine, 1–2 ASW aircraft	Generally 2–4 days	SOCAL HRC	ARG/MEU, ID CERTEX/ASW, Group Sail	Less than 50 hours

Notes: ASW = Anti-Submarine Warfare, SOCAL = Southern California Range Complex, PMSR = Point Mugu Sea Range Overlap, HRC = Hawaii Range Complex, RIMPAC = Rim of the Pacific, COMPTUEX = Composite Training Unit Exercise, FLEETEX/SUSTEX = Fleet Exercise/Sustainment Exercise, USWEX = Undersea Warfare Exercise, SWATT = Surface Warfare Advanced Tactical Training, NUWTAC = Naval Undersea Warfare Training Assessment Course, SCC = Submarine Command Course, ARG/MEU CERTEX = Amphibious Ready Group/Marine Expeditionary Unit Certification Exercise, ID CERTEX/ASW = Independent Deployer Certification Exercise/Tailored Anti-submarine Warfare Training

[1]PMSR indicates only the portion of the Point Mugu Sea Range that overlaps the Southern California portion of the HSTT Study Area, as described in Section 2.1.2.2 (Point Mugu Sea Range Overlap).

Table 2.3-2: Proposed Training Activities

Activity Name	*Activity Description*
	Major Training Exercises – Large Integrated Anti-Submarine Warfare
Composite Training Unit Exercise	Aircraft carrier and its associated aircraft integrate with surface and submarine units in a challenging multi-threat operational environment in order to certify them for deployment. Only the anti-submarine warfare portion of a Composite Training Unit Exercise is included in this activity; other training objectives are met via unit-level training described in each of the Primary Mission Areas below.
Rim of the Pacific Exercise	A biennial multinational training exercise in which navies from Pacific Rim nations and other allies assemble in Pearl Harbor, Hawaii, to conduct training throughout the Hawaiian Islands in a number of warfare areas. Components of a Rim of the Pacific exercise such as mine warfare, surface warfare, and amphibious training are conducted in the Southern California Range Complex.
	Major Training Exercises – Medium Integrated Anti-Submarine Warfare
Fleet Exercise/ Sustainment Exercise	Aircraft carrier and its associated aircraft integrate with surface and submarine units in a challenging multi-threat operational environment in order to maintain their ability to deploy. Fleet Exercises and Sustainment Exercises are similar to Composite Training Unit Exercises, but are shorter in duration.
Undersea Warfare Exercise	Elements of the anti-submarine warfare tracking exercise combine in this exercise of multiple air, surface, and subsurface units, over a period of several days.
	Integrated/Coordinated Training – Small Integrated Anti-Submarine Warfare
Naval Undersea Warfare Training Assessment Course	Multiple ships, aircraft, and submarines integrate the use of their sensors to search for, detect, classify, localize, and track a threat submarine in order to launch an exercise torpedo.
Surface Warfare Advanced Tactical Training	Multiple ships and aircraft use sensors, including sonobuoys, to search, detect, and track a threat submarine. Surface Warfare Advanced Tactical Training exercises are not dedicated anti-submarine warfare events and involve multiple warfare areas.
	Integrated/Coordinated Training – Medium Coordinated Anti-Submarine Warfare
Submarine Command Course	Train prospective submarine Commanding Officers to operate against surface, air, and subsurface threats.
	Integrated/Coordinated Training – Small Coordinated Anti-Submarine Warfare
Amphibious Ready Group/Marine Expeditionary Unit Exercise	Navy and Marine Corps forces conduct advanced training at sea in preparation for deployment.
Group Sail	Surface ships and rotary-wing aircraft search for, detect, and track threat submarines. Group Sails are not dedicated anti-submarine warfare events and involve multiple warfare areas; non-anti-submarine warfare training objectives are met via unit-level training described in the Primary Mission Areas below.

Table 2.3-2: Proposed Training Activities (continued)

Activity Name	*Activity Description*
Integrated/Coordinated Training – Small Coordinated Anti-Submarine Warfare Training (continued)	
Independent Deployer Certification Exercise/Tailored Anti-Submarine Warfare Training	Multiple ships and helicopters integrate the use of their sensors, including sonobuoys, to search for, detect, classify, localize and track a threat submarine to launch a torpedo.
Air Warfare	
Air Combat Maneuver	Fixed-wing aircrews aggressively maneuver against threat aircraft to gain tactical advantage.
Air Defense Exercise	Aircrew and ship crews conduct defensive measures against threat aircraft or simulated missiles.
Gunnery Exercise Air-to-Air Medium-caliber	Fixed-wing aircraft fire medium-caliber guns at air targets.
Gunnery Exercise Surface-to-Air Large-caliber	Surface ship crews fire large-caliber guns at air targets.
Gunnery Exercise Surface-to-Air Medium-caliber	Surface ship crews fire medium-caliber guns at air targets.
Missile Exercise Air-to-Air	Fixed-wing and helicopter aircrews fire air-to-air missiles at air targets.
Missile Exercise – Man-portable Air Defense System	Personnel employ shoulder-fired surface-to-air missiles at air targets.
Missile Exercise Surface-to-Air	Surface ship crews fire surface-to-air missiles at air targets.
Amphibious Warfare	
Amphibious Assault	Large unit forces move ashore from amphibious ships at sea for the immediate execution of inland objectives.
Amphibious Assault – Battalion Landing	Marine Corps Battalion Landing Team forces launch an attack from sea to a hostile shore for the immediate execution of inland maneuvers (e.g., Dawn Blitz).
Amphibious Marine Expeditionary Unit Exercise	Navy and Marine Corps forces conduct advanced integration training in preparation for deployment certification.
Amphibious Marine Expeditionary Unit Integration Exercise	Navy and Marine Corps forces conduct integration training at sea in preparation for deployment certification.
Amphibious Raid	Small unit forces move from amphibious ships at sea to shore locations for a specific short-term mission. These are quick operations with as few personnel as possible.

Table 2.3-2: Proposed Training Activities (continued)

Activity Name	*Activity Description*
Amphibious Warfare (continued)	
Expeditionary Fires Exercise/Supporting Arms Coordination Exercise	Military units provide integrated and effective close air support, Naval Surface Fire Support fire, and Marine Corps artillery/mortar fire in support of amphibious operations.
Humanitarian Assistance Operations	Navy and Marine Corps forces evacuate noncombatants from hostile or unsafe areas or provide humanitarian assistance in times of disaster.
Marine Expeditionary Unit Composite Training Unit Exercise	Amphibious Ready Group exercises are conducted to validate the Marine Expeditionary Unit's readiness for deployment and include small boat raids; visit, board, search, and seizure training; helicopter and mechanized amphibious raids; and a non-combatant evacuation operation.
Naval Surface Fire Support Exercise-At Sea	Surface ship crews use large-caliber guns to support forces ashore; however, the land target is simulated at sea. Rounds are scored by a passive acoustic hydrophone scoring system.
Naval Surface Fire Support Exercise – Land-Based Target	Surface ship crews fire large-caliber guns at land-based targets to support forces ashore.
Anti-Submarine Warfare	
Anti-Submarine Warfare Torpedo Exercise – Helicopter	Helicopter crews search for, track, and detect submarines. Recoverable air launched torpedoes are employed against submarine targets.
Anti-Submarine Warfare Torpedo Exercise – Maritime Patrol Aircraft	Maritime patrol aircraft aircrews search for, track, and detect submarines. Recoverable air launched torpedoes are employed against submarine targets.
Anti-Submarine Warfare Torpedo Exercise – Ship	Surface ship crews search for, track, and detect submarines. Exercise torpedoes are used.
Anti-Submarine Warfare Torpedo Exercise – Submarine	Submarine crews search for, track, and detect submarines. Exercise torpedoes are used.
Anti-Submarine Warfare Tracking Exercise – Helicopter	Helicopter crews search for, track, and detect submarines.
Anti-Submarine Warfare Tracking Exercise – Maritime Patrol Aircraft	Maritime patrol aircraft aircrews search for, track, and detect submarines.
Anti-Submarine Warfare Tracking Exercise -Ship	Surface ship crews search for, track, and detect submarines.
Anti-Submarine Warfare Tracking Exercise - Submarine	Submarine crews search for, track, and detect submarines.
Service Weapons Test	Air, surface, or submarine crews employ explosive torpedoes against targets.

Table 2.3-2: Proposed Training Activities (continued)

Activity Name	*Activity Description*
Electronic Warfare	
Counter Targeting Chaff Exercise – Aircraft	Fixed-wing aircraft and helicopter aircrews deploy chaff to disrupt threat targeting and missile guidance radars.
Counter Targeting Chaff Exercise – Ship	Surface ship crews deploy chaff to disrupt threat targeting and missile guidance radars.
Counter Targeting Flare Exercise	Fixed-wing aircraft and helicopter aircrews deploy flares to disrupt threat infrared missile guidance systems.
Electronic Warfare Operations	Aircraft and surface ship crews control the electromagnetic spectrum used by enemy systems to degrade or deny the enemy's ability to take defensive actions.
Expeditionary Warfare	
Dive and Salvage Operations	Navy divers perform dive operations and salvage training.
Personnel Insertion/Extraction – Surface and subsurface	Personnel are inserted into and extracted from an objective area by small boats or subsurface platforms.
Personnel Insertion/Extraction Training – Swimmer/Diver	Divers and swimmers infiltrate harbors, beaches, or moored vessels and conduct a variety of tasks.
Small Boat Attack	Afloat units defend against attacking watercraft. For this activity, one or two small boats or personal watercraft conduct attack activities on units afloat.
Mine Warfare	
Airborne Mine Countermeasure – Mine Detection	Helicopter aircrews detect mines using towed or laser mine detection systems.
Civilian Port Defense – Homeland Security Anti-Terrorism/Force Protection Exercise	Maritime security personnel train to protect civilian ports against enemy efforts to interfere with access to those ports.
Limpet Mine Neutralization System	Navy Explosive Ordnance Disposal divers place a small charge on a simulated underwater mine.
Marine Mammal Systems	The Navy deploys trained bottlenose dolphins (*Tursiops truncatus*) and California sea lions (*Zalophus californianus*) as part of the marine mammal mine-hunting and object-recovery system.
Mine Countermeasure Exercise – Ship Sonar	Ship crews detect and avoid mines while navigating restricted areas or channels using active sonar.
Mine Countermeasure Exercise – Surface	Ship crews detect, locate, identify, and avoid mines while navigating restricted areas or channels, such as while entering or leaving port.

Table 2.3-2: Proposed Training Activities (continued)

Activity Name	*Activity Description*
Mine Warfare (continued)	
Mine Countermeasures – Mine Neutralization – Remotely Operated Vehicle	Ship, small boat, and helicopter crews locate and disable mines using remotely operated underwater vehicles.
Mine Countermeasures – Towed Mine Neutralization	Helicopter aircrews and unmanned vehicles tow systems through the water, which are designed to disable or trigger mines.
Mine Laying	Fixed-wing aircraft drop non-explosive mine shapes.
Mine Neutralization Explosive Ordnance Disposal	Personnel disable threat mines using explosive charges.
Submarine Launched Mobile Mines Exercise	Submarine crews practice deploying submarine launched mobile mines.
Submarine Mine Exercise	Submarine crews practice detecting mines in a designated area.
Surface Ship Object Detection	Ship crews detect and avoid mines while navigating restricted areas or channels, using active sonar.
Underwater Demolitions Multiple Charge – Mat Weave and Obstacle Loading	Military personnel use explosive charges to destroy barriers or obstacles to amphibious vehicle access to beach areas.
Underwater Demolition Qualification and Certification	Navy divers conduct various levels of training and certification in placing underwater demolition charges.
Surface Warfare	
Bombing Exercise Air-to-Surface	Fixed-wing aircrews deliver bombs against surface targets.
Gunnery Exercise Air-to-Surface Medium-caliber	Fixed-wing and helicopter aircrews fire medium-caliber guns at surface targets.
Gunnery Exercise Air-to-Surface Small-caliber	Helicopter and tilt-rotor aircrews use small-caliber guns to engage surface targets.
Gunnery Exercise Surface-to-Surface Boat Medium-Caliber	Small boat crews fire medium-caliber guns at surface targets.
Gunnery Exercise Surface-to-Surface Boat Small-Caliber	Small boat crews fire small-caliber guns at surface targets.
Gunnery Exercise Surface-to-Surface Ship Large-caliber	Surface ship crews fire large-caliber guns at surface targets.

Table 2.3-2: Proposed Training Activities (continued)

Activity Name	*Activity Description*
Surface Warfare (continued)	
Gunnery Exercise Surface-to-Surface Ship Medium-Caliber	Surface ship crews fire medium-caliber guns at surface targets.
Gunnery Exercise Surface-to-Surface Ship Small-Caliber	Surface ship crews fire small-caliber guns at surface targets.
Independent Deployer Certification Exercise/Tailored Surface Warfare Training	Multiple ships, aircraft, and submarines conduct integrated multi-warfare training with a surface warfare emphasis. Serves as a ready-to-deploy certification for individual surface ships tasked with surface warfare missions.
Integrated Live Fire Exercise	Naval Forces defend against multiple surface threats (ships or small boats) with bombs, missiles, rockets, and small-, medium- and large-caliber guns.
Laser Targeting - Aircraft	Fixed-wing and helicopter aircrews illuminate targets with targeting and directed energy lasers.
Maritime Security Operations	Helicopter, surface ship, and small boat crews conduct security operations at sea, to include visit, board, search and seizure; maritime interdiction operations; force protection; and anti-piracy operations.
Missile Exercise Air-to-Surface	Fixed-wing and helicopter aircrews fire air-to-surface missiles at surface targets.
Missile Exercise Air-to-Surface Rocket	Helicopter aircrews fire both precision-guided and unguided rockets at surface targets.
Missile Exercise Surface-to-Surface	Surface ship crews defend against surface threats (ships or small boats) and engage them with missiles.
Sinking Exercise	Aircraft, ship, and submarine crews deliberately sink a seaborne target, usually a decommissioned ship made environmentally safe for sinking according to U.S. Environmental Protection Agency standards, with a variety of munitions.
Other Training Exercises	
Elevated Causeway System	A temporary pier is constructed off the beach. Support pilings are driven into the sand and then later removed.
Kilo Dip	Functional check of the dipping sonar prior to conducting a full test or training event on the dipping sonar.
Offshore Petroleum Discharge System	Personnel transfer petroleum from ship to shore (water is used to simulate petroleum during the training).
Precision Anchoring	Surface ship crews release and retrieve anchors in designated locations.
Submarine Navigation	Submarine crews operate sonar for navigation and object detection while transiting into and out of port during reduced visibility.

Table 2.3-2: Proposed Training Activities (continued)

Activity Name	*Activity Description*
Other Training Exercises (continued)	
Submarine Sonar Maintenance and Systems Checks	Maintenance of submarine sonar systems is conducted pierside or at sea.
Submarine Under Ice Certification	Submarine crews train to operate under ice. Ice conditions are simulated during training and certification events.
Surf Zone Test Detachment/Equipment Test and Evaluation	Navy personnel test and evaluate the effectiveness of new detection and neutralization equipment designed for surf conditions.
Surface Ship Object Detection	Surface ship crews operate sonar for navigation and object detection while transiting into and out of port during reduced visibility.
Surface Ship Sonar Maintenance and Systems Checks	Maintenance of surface ship sonar systems is conducted pierside or at sea.
Unmanned Aerial System Training and Certification	Submarines launch unmanned aerial systems while submerged.
Unmanned Underwater Vehicle Training - Certification and Development	Unmanned underwater vehicle certification involves training with unmanned platforms to ensure submarine crew proficiency. Tactical development involves training with various payloads, for multiple purposes to ensure that the systems can be employed effectively in an operational environment.
Waterborne Training	Small boat crews conduct a variety of training, including boat launch and recovery, operation of crew-served unmanned vehicles, mooring to buoys, anchoring, and maneuvering. Small boats include rigid hull inflatable boats, and riverine patrol, assault, and command boats up to approximately 50 feet in length.

2.3.2 Proposed Testing Activities

The Navy's research and acquisition community engages in a broad spectrum of testing activities in support of the fleet. These activities include, but are not limited to, basic and applied scientific research and technology development; testing, evaluation, and maintenance of systems (e.g., missiles, radar, and sonar) and platforms (e.g., surface ships, submarines, and aircraft); and acquisition of systems and platforms to support Navy missions and give a technological edge over adversaries. The individual commands within the research and acquisition community included in this EIS/OEIS are Naval Air Systems Command, Naval Sea Systems Command, Office of Naval Research, and Space and Naval Warfare Systems Command.

The Navy operates in an ever-changing strategic, tactical, financially constrained, and time-constrained environment. Testing activities occur in response to emerging science or fleet operational needs. For example, future Navy experiments to develop a better understanding of ocean currents may be designed based on advancements made by non-government researchers not yet published in the scientific literature. Similarly, future but yet unknown Navy operations within a specific geographic area may require development of modified Navy assets to address local conditions. Such modifications must be tested in the field to ensure they meet fleet needs and requirements. Accordingly, generic descriptions of some of these activities are the best that can be articulated in a long-term, comprehensive document, like this EIS/OEIS.

Some testing activities are similar to training activities conducted by the fleet. For example, both the fleet and the research and acquisition community fire torpedoes. While the firing of a torpedo might look identical to an observer, the difference is in the purpose of the firing. The fleet might fire the torpedo to practice the procedures for such a firing, whereas the research and acquisition community might be assessing a new torpedo guidance technology, testing it to ensure that the torpedo meets performance specifications and operational requirements.

2.3.2.1 Naval Air Systems Command Testing Activities

Naval Air Systems Command testing activities generally fall in the primary mission areas used by the fleets. Naval Air Systems Command activities include, but are not limited to, the testing of new aircraft platforms (e.g., the F-35 Joint Strike Fighter aircraft), weapons, and systems (e.g., newly developed sonobuoys) that will ultimately be integrated into fleet training activities. In addition to the testing of new platforms, weapons, and systems, Naval Air Systems Command also conducts lot acceptance testing of weapons and systems, such as sonobuoys.

The majority of testing activities conducted by Naval Air Systems Command are similar to fleet training activities, and many platforms and systems currently being tested are already being used by the fleet or will ultimately be integrated into fleet training activities. However, some testing activities may be conducted in different locations and in a different manner than similar fleet training activities, and, therefore, the analysis for those events and the potential environmental effects may differ. Training with systems and platforms delivered to the fleet within the timeframe of this document are analyzed in the training sections of this EIS/OEIS. Table 2.3-3 addresses Naval Air Systems Command's proposed testing activities.

Table 2.3-3 Naval Air Systems Command's Proposed Testing Activities

Activity Name	***Activity Description***
Air Warfare	
Air Combat Maneuver Test	Aircrews engage in flight maneuvers designed to gain a tactical advantage during combat.
Air Platform Weapons Integration Test	Testing performed to quantify the compatibility of weapons with the aircraft from which they would be launched or released. Non-explosive weapons or shapes are used.
Air Platform-Vehicle Test	Testing performed to quantify the flying qualities, handling, airworthiness, stability, controllability, and integrity of an air platform or vehicle. No explosive weapons are released during an air platform-vehicle test.
Intelligence, Surveillance, and Reconnaissance Test	Aircrews use all available sensors to collect data on threat vessels.

Table 2.3-3: Naval Air Systems Command's Proposed Testing Activities (continued)

Activity Name	Activity Description
Anti-Submarine Warfare	
Anti-Submarine Warfare – Torpedo Test	This event is similar to the training event torpedo exercise. Test evaluates anti-submarine warfare systems onboard rotary-wing and fixed-wing aircraft and the ability to search for, detect, classify, localize, track, and attack a submarine or similar target.
Anti-Submarine Warfare Tracking Test – Helicopter	This event is similar to the training event anti-submarine tracking exercise-helicopter. The test evaluates the sensors and systems used to detect and track submarines and to ensure that helicopter systems used to deploy the tracking systems perform to specifications.
Anti-Submarine Warfare Tracking Test – Maritime Patrol Aircraft	The test evaluates the sensors and systems used by maritime patrol aircraft to detect and track submarines and to ensure that aircraft systems used to deploy the tracking systems perform to specifications and meet operational requirements.
Sonobuoy Lot Acceptance Test	Sonobuoys are deployed from surface vessels and aircraft to verify the integrity and performance of a lot or group of sonobuoys in advance of delivery to the fleet for operational use.
Electronic Warfare	
Chaff Test	This event is similar to the training event chaff exercise. Chaff tests evaluate newly developed or enhanced chaff, chaff dispensing equipment, or modified aircraft systems against chaff deployment. Tests may also train pilots and aircrew in the use of new chaff dispensing equipment. Chaff tests are often conducted with flare tests and air combat maneuver events, as well as other test events, and are not typically conducted as standalone tests.
Electronic Systems Evaluation	Test that evaluates the effectiveness of electronic systems to control, deny, or monitor critical portions of the electromagnetic spectrum. In general, electronic warfare testing will assess the performance of three types of electronic warfare systems: electronic attack, electronic protect, and electronic support.
Flare Test	This event is similar to the training event flare exercise. Flare tests evaluate newly developed or enhanced flares, flare dispensing equipment, or modified aircraft systems against flare deployment. Tests may also train pilots and aircrew in the use of newly developed or modified flare deployment systems. Flare tests are often conducted with chaff tests and air combat maneuver events, as well as other test events, and are not typically conducted as standalone tests.
Mine Warfare	
Airborne Dipping Sonar Minehunting Test	A mine-hunting dipping sonar system that is deployed from a helicopter and uses high-frequency sonar for the detection and classification of bottom and moored mines.
Airborne Laser-Based Mine Detection System Test	An airborne mine hunting test of a laser-based mine detection system, that is operated from a helicopter and evaluates the system's ability to detect, classify, and fix the location of floating and near-surface, moored mines. The system uses a non-weaponized laser to locate mines.

Table 2.3-3: Naval Air Systems Command's Proposed Testing Activities (continued)

Activity Name	*Activity Description*
Mine Warfare (continued)	
Airborne Mine Neutralization System Test	A test of the airborne mine neutralization system evaluates the system's ability to detect and destroy mines from an airborne mine countermeasures capable helicopter. The Airborne Mine Neutralization System uses up to four unmanned underwater vehicles equipped with high-frequency sonar, video cameras, and explosive and non-explosive neutralizers.
Airborne Sonobuoy Minehunting Test	A mine-hunting system made up of sonobuoys deployed from a helicopter. A field of sonobuoys, using high-frequency sonar, is used to detect and classify bottom and moored mines.
Mine Laying Test	Fixed-wing aircraft evaluate the performance of mine laying equipment and software systems to lay mines. A mine test may also train aircrew in laying mines using a new or enhanced mine deployment system.
Surface Warfare	
Air-to-Surface Bombing Test	This event is similar to the training event bombing exercise air-to-surface. Fixed-wing aircraft test the delivery of bombs against surface maritime targets with the goal of evaluating the bomb, the bomb carry and delivery system, and any associated systems that may have been newly developed or enhanced.
Air-to-Surface Gunnery Test	This event is similar to the training event gunnery exercise air-to-surface. Fixed-wing and rotary-wing aircrews evaluate new or enhanced aircraft guns against surface maritime targets to test that the gun, gun ammunition, or associated systems meet required specifications or to train aircrew in the operation of a new or enhanced weapon system.
Air-to-Surface Missile Test	This event is similar to the training event missile exercise air-to-surface. Test may involve both fixed-wing and rotary-wing aircraft launching missiles at surface maritime targets to evaluate the weapons system or as part of another system's integration test.
High Energy Laser Weapons Test	High-energy laser weapons tests evaluate the specifications, integration, and performance of an aircraft mounted high-energy laser which can be used as a weapon to disable small surface vessels.
Laser Targeting Test	Aircrews illuminate enemy targets with lasers.
Rocket Test	Rocket tests evaluate the integration, accuracy, performance, and safe separation of guided and unguided 2.75-inch rockets fired from a hovering or forward flying helicopter.
Other Testing Activities	
Acoustic and Oceanographic Research	Active transmissions within the band 10 hertz–100 kilohertz from sources deployed from ships and aircraft.
Air Platform Shipboard Integrate Test	Fixed-wing and rotary-wing aircraft are tested to determine operability from shipboard platforms, performance of shipboard physical operations, and to verify and evaluate communications and tactical data links.

Table 2.3-3: Naval Air Systems Command's Proposed Testing Activities (continued)

Activity Name	*Activity Description*
Other Testing Activities (continued)	
Kilo Dip	Functional check of a helicopter deployed dipping sonar system prior to conducting a testing or training event using the dipping sonar system.
Shipboard Electronic Systems Evaluation	Tests measure ship antenna radiation patterns and test communication systems with a variety of aircraft.
Undersea Range System Test	Following installation of a Navy underwater warfare training and testing range, tests of the nodes (components of the range) will be conducted to include node surveys and testing of node transmission functionality.

2.3.2.2 Naval Sea Systems Command Testing Activities

Naval Sea Systems Command projected testing activities are generally aligned with the primary mission areas used by the fleets. Naval Sea Systems Command activities include, but are not limited to, new ship construction, life cycle support, and other weapon system development and testing. In this EIS/OEIS, only systems testing at Navy shipyards and piers is included.

Testing activities are conducted throughout the life of a Navy ship, from construction to verification of performance and mission capabilities, to deactivation from the fleet. Activities include pierside and at-sea testing of ship systems, including sonar, acoustic countermeasures, radars, torpedoes, weapons, unmanned systems, and radio equipment; tests to determine how the ship performs at sea (sea trials); development and operational test and evaluation programs for new technologies and systems; and testing on all ships and systems that have undergone overhaul or maintenance. Table 2.3-4 describes Naval Sea Systems Command's proposed testing activities.

Table 2.3-4: Naval Sea Systems Command's Proposed Testing Activities

Activity Name	*Activity Description*
Anti-Submarine Warfare	
Anti-Submarine Warfare Mission Package Testing	Ships and their supporting platforms (e.g., rotary-wing aircraft, unmanned aerial systems) detect, localize, and prosecute submarines.
At-Sea Sonar Testing	At-sea testing to ensure systems are fully functional in an open ocean environment.
Countermeasure Testing	Countermeasure testing involves the testing of systems that will detect, localize, and track incoming weapons including marine vessel targets. Testing includes surface ship torpedo defense systems and marine vessel stopping payloads.
Pierside Sonar Testing	Pierside testing to ensure systems are fully functional in a controlled pierside environment prior to at-sea test activities.
Submarine Sonar Testing/Maintenance	Pierside and at-sea testing of submarine systems occurs periodically following major maintenance periods and for routine maintenance.

Table 2.3-4: Naval Sea Systems Command's Proposed Testing Activities (continued)

Activity Name	*Activity Description*
	Anti-Submarine Warfare (continued)
Surface Ship Sonar Testing/Maintenance	Pierside and at-sea testing of ship systems occur periodically following major maintenance periods and for routine maintenance.
Torpedo (Explosive) Testing	Air, surface, or submarine crews employ explosive and non-explosive torpedoes against artificial targets.
Torpedo (Non-Explosive) Testing	Air, surface, or submarine crews employ non-explosive torpedoes against submarines, surface vessels, or artificial targets.
	Electronic Warfare
Radar and Other System Testing	Test may include use of military or commercial radar, communication systems (or simulators), or high-energy lasers. Testing may occur aboard a ship against drones, small boats, rockets, missiles, or other targets.
	Mine Warfare
Mine Countermeasure and Neutralization Testing	Air, surface, and subsurface vessels neutralize threat mines and mine-like objects.
Mine Countermeasure Mission Package Testing	Vessels and associated aircraft conduct mine countermeasure operations.
Mine Detection and Classification Testing	Air, surface, and subsurface vessels and systems detect, classify, and avoid mines and mine-like objects. Vessels also assess their potential susceptibility to mines and mine-like objects.
	Surface Warfare
Gun Testing – Large-Caliber	Surface crews test large-caliber guns to defend against surface targets.
Gun Testing – Medium-Caliber	Surface crews test medium-caliber guns to defend against surface targets.
Gun Testing – Small-Caliber	Surface crews test small-caliber guns to defend against surface targets.
Kinetic Energy Weapon Testing	A kinetic energy weapon uses stored energy released in a burst to accelerate a projectile.
Missile and Rocket Testing	Missile and rocket testing includes various missiles or rockets fired from submarines and surface combatants. Testing of the launching system and ship defense is performed.
	Unmanned Systems
Unmanned Surface Vehicle System Testing	Testing involves the production and/or upgrade of unmanned surface vehicles. This may include testing of mine detection capabilities, evaluating the basic functions of individual platforms, or complex events with multiple vehicles.
Unmanned Underwater Vehicle Testing	Testing involves the production and/or upgrade of unmanned underwater vehicles. This may include testing of mine detection capabilities, evaluating the basic functions of individual platforms, or complex events with multiple vehicles.

Table 2.3-4: Naval Sea Systems Command's Proposed Testing Activities (continued)

Activity Name	*Activity Description*
Vessel Evaluation	
Air Defense Testing	Test the ship's capability to detect, identify, track, and successfully engage live and simulated targets. Gun systems are tested using explosive and non-explosive rounds.
In-Port Maintenance Testing	Each combat system is tested to ensure they are functioning in a technically acceptable manner and are operationally ready to support at-sea Combat System Ship Qualification Trial events.
Propulsion Testing	Ship is run at high speeds in various formations (e.g., straight-line and reciprocal paths).
Submarine Sea Trials – Propulsion Testing	Submarine is run at high speeds in various formations and depths.
Submarine Sea Trials – Weapons System Testing	Submarine weapons and sonar systems are tested at-sea to meet integrated combat system certification requirements.
Surface Warfare Testing	Tests capability of shipboard sensors to detect, track, and engage surface targets. Testing may include ships defending against surface targets using explosive and non-explosive rounds, gun system structural test firing, and demonstration of the response to Call for Fire against land based targets (simulated by sea-based locations).
Undersea Warfare Testing	Ships demonstrate capability of countermeasure systems and underwater surveillance, weapons engagement and communications systems. This tests ships ability to detect, track, and engage undersea targets.
Vessel Signature Evaluation	Surface ship, submarine, and auxiliary system signature assessments. This may include electronic, radar, acoustic, infrared, and magnetic signatures.
Other Testing Activities	
Chemical and Biological Simulant Testing	Chemical-biological agent simulants are deployed against surface ships.
Insertion/Extraction	Testing of submersibles capable of inserting and extracting personnel and payloads into denied areas from strategic distances.
Non-Acoustic Component Testing	Tests of towed or floating buoys for communications through radio frequencies or two-way optical communications between an aircraft and underwater system(s).
Signature Analysis Operations	Surface ship and submarine testing of electromagnetic, acoustic, optical, and radar signature measurements.

2.3.2.3 Office of Naval Research Testing Activities

As the Department of the Navy's science and technology provider, the Office of Naval Research provides technology solutions for Navy and Marine Corps needs. The Office of Naval Research's mission is to plan, foster, and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power, and the preservation of national security. The Office of Naval

Research manages the Navy's basic, applied, and advanced research to foster transition from science and technology to higher levels of research, development, test, and evaluation. The Office of Naval Research is also a parent organization for the Naval Research Laboratory, which operates as the Navy's corporate research laboratory and conducts a broad multidisciplinary program of scientific research and advanced technological development. Testing conducted by the Office of Naval Research in the HSTT Study Area includes acoustic and oceanographic research, large displacement unmanned underwater vehicle (innovative naval prototype) research, and emerging mine countermeasure technology research. Table 2.3-5 describes the Office of Naval Research's proposed testing activities.

Table 2.3-5: Office of Naval Research Proposed Testing Activities

Activity Name	***Activity Description***
Acoustic and Oceanographic Science and Technology	
Acoustic and Oceanographic Research	Research using active transmissions from sources deployed from ships, aircraft, and unmanned underwater vehicles. Research sources can be used as proxies for current and future Navy systems.
Large Displacement Unmanned Underwater Vehicle Testing	Autonomy testing and environmental data collection with Large Displacement Unmanned Underwater Vehicles.
Long Range Acoustic Communications	Low-frequency bottom-mounted acoustic source off of the Hawaiian Island of Kauai will transmit a variety of acoustic communications sequences.

2.3.2.4 Space and Naval Warfare Systems Command Testing Activities

Space and Naval Warfare Systems Command is the information warfare systems command for the U.S. Navy. The mission of the Space and Naval Warfare Systems Command is to acquire, develop, deliver, and sustain decision superiority for the warfighter. Space and Naval Warfare Systems Center Pacific is the research and development part of Space and Naval Warfare Systems Command focused on developing and transitioning technologies in the area of command, control, communications, computers, intelligence, surveillance, and reconnaissance. Space and Naval Warfare Systems Center Pacific conducts research, development, test, and evaluation projects to support emerging technologies for intelligence, surveillance, and reconnaissance; anti-terrorism and force protection; mine countermeasures; anti-submarine warfare; oceanographic research; remote sensing; and communications. These activities include, but are not limited to, the testing of surface and subsurface vehicles; intelligence, surveillance, and reconnaissance/information operations sensor systems; underwater surveillance technologies; and underwater communications.

Table 2.3-6 describes the typical and anticipated Space and Naval Warfare Systems Command and Space and Naval Warfare Systems Command Systems Center Pacific test and evaluation activities to be conducted in the Study Area.

Table 2.3-6: Space and Naval Warfare Systems Command's Proposed Testing Activities

Activity Name	***Activity Description***
Other Testing Activities	
Anti-Terrorism/Force Protection	Testing sensor systems that can detect threats to naval piers, ships and shore infrastructure.
Communications	Testing of underwater communications and networks to extend the principles of FORCEnet below the ocean surface.
Energy and Intelligence, Surveillance, and Reconnaissance/Information Operations Sensor Systems	Develop, integrate, and demonstrate ISR systems and in-situ energy systems to support deployed systems.
Vehicle Testing	Testing of surface and subsurface vehicles and sensor systems, which may involve unmanned underwater vehicles, gliders, unmanned surface vehicles and unmanned aerial systems.

2.3.3 STANDARD OPERATING PROCEDURES

For training and testing to be effective, units must be able to safely use their sensors and weapon systems as they are intended to be used in military missions and combat operations and to their optimum capabilities. Standard operating procedures applicable to training and testing have been developed through years of experience, and their primary purpose is to provide for safety (including public health and safety) and mission success. In many cases, there are benefits to environmental and cultural resources (some of which have a high socioeconomic value in the Study Area) resulting from standard operating procedures. Navy standard operating procedures are published or broadcast via numerous naval instructions and manuals, including but not limited to:

- Ship, submarine, and aircraft safety manuals
- Ship, submarine, and aircraft standard operating manuals
- Fleet Area Control and Surveillance Facility range operating instructions
- Fleet exercise publications and instructions
- Naval Sea Systems Command test range safety and standard operating instructions
- Navy instrumented range operating procedures
- Naval shipyard sea trial agendas
- Research, development, test, and evaluation plans
- Naval gunfire safety instructions
- Navy planned maintenance system instructions and requirements
- Federal Aviation Administration regulations
- International Regulations for Preventing Collisions at Sea

Because they are essential to safety and mission success, standard operating procedures are part of the Proposed Action and are considered in the Chapter 3 (Affected Environment and Environmental

Consequences) environmental analysis for applicable resources. Standard operating procedures that provide a benefit to public health and safety, environmental resources, or cultural resources are discussed in the sections below and included in Appendix A (Navy Activity Descriptions).

Standard operating procedures (which are implemented for the purpose of safety and mission success) are different from mitigation measures (which are implemented for the purpose of avoiding or reducing potential impacts on environmental and cultural resources). A brief introduction to the activities, stressor categories, and geographic areas for which the Navy will implement mitigation is provided in Section 2.3.4 (Mitigation Measures). A full discussion of mitigation measures is presented in Chapter 5 (Mitigation) and Appendix K (Geographic Mitigation Assessment).

2.3.3.1 Sea Space and Airspace Deconfliction

The Navy schedules training and testing activities to minimize conflicts with the use of sea space and airspace within ranges and throughout the Study Area to ensure the safety of Navy personnel, the public, commercial aircraft, commercial and recreational vessels, and military assets. The Navy deconflicts its own use of sea space and airspace to allow for the necessary separation of multiple Navy units to prevent interference with equipment sensors and avoid interaction with established commercial air traffic routes and commercial shipping lanes. These standard operating procedures benefit public health and safety (including persons participating in activities that have socioeconomic value, such as recreational or commercial fishing) through a reduction in the potential for interactions with training and testing activities.

2.3.3.2 Vessel Safety

Navy vessels are required to operate in accordance with applicable navigation rules, including Inland Navigation Rules (33 CFR 83) and International Regulations for Preventing Collisions at Sea (72 COLREGS), which were formalized in the Convention on the International Regulations for Preventing Collisions at Sea, 1972. Applicable navigation requirements include, but are not limited to, Rule 5 (Lookouts) and Rule 6 (Safe Speed). These rules require that vessels at all times proceed at a safe speed so proper and effective action can be taken to avoid collision and so vessels can be stopped within a distance appropriate to the prevailing circumstances and conditions. Navy ships transit at speeds that are optimal for fuel conservation, to maintain ship schedules, and to meet mission requirements. Vessel captains use the totality of the circumstances to ensure the vessel is traveling at appropriate speeds in accordance with navigation rules. Depending on the circumstances, this may involve adjusting speeds during periods of reduced visibility or in certain locations. Information about operating speeds of the vessels that will be used under the Proposed Action is provided in Section 3.0.3.3.4.1 (Vessels and In-Water Devices). With limited exceptions (e.g., amphibious vessels operating in designated locations), Navy vessels avoid contact with the seafloor as a standard collision avoidance procedure to prevent damage to vessels. The Navy also avoids known navigation hazards that appear on nautical charts, such as submerged wrecks and obstructions.

Ships operated by or for the Navy have personnel assigned to stand watch at all times, day and night, when moving through the water (underway) for safety of navigation, collision avoidance, range clearance, and man-overboard precautions. Watch personnel include officers, enlisted men and women, and civilians operating in similar capacities. To qualify to stand watch, personnel undertake extensive training that includes, but is not limited to, on-the-job instruction and a formal Personal Qualification Standard program (or equivalent program for civilians) to certify that they have demonstrated all necessary skills. While on watch, personnel employ visual search and reporting procedures in accordance with the U.S. Navy Lookout Training Handbook or civilian equivalent. Watch personnel are responsible for using correct scanning procedures while monitoring an assigned sector; estimating relative bearing, range, position angle, and target angle of sighted objects; and rapidly sending accurate reports of all visual information to the bridge and combat information center. After sunset and prior to sunrise, watch personnel employ night visual search techniques, which could include the use of night vision devices.

Watch personnel monitor their assigned sectors for any indication of danger to the ship and the personnel on board, such as a floating or partially submerged object or piece of debris, periscope, surfaced submarine, wisp of smoke, flash of light, or surface disturbance. As a standard collision avoidance procedure, watch personnel also monitor for marine mammals that have the potential to be in the direct path of the ship. Watch personnel duties may be performed in conjunction with other tasks or job responsibilities, such as navigating the ship or supervising other personnel. Watch personnel are not normally posted while ships are moored to a pier. When anchored or moored to a buoy, a watch team is still maintained but with fewer personnel than when underway.

The standard operating procedures for vessel safety benefit public health and safety, marine mammals, cultural resources, and seafloor resources through a reduction in the potential for vessel strikes.

2.3.3.3 Aircraft Safety

Pilots of Navy aircraft make every attempt to avoid large flocks of birds to reduce the safety risk involved with a potential bird strike. Since 2011, the Navy has required that all Navy flying units report all bird strikes through the Web-Enabled Safety System Aviation Mishap and Hazard Reporting System. The standard operating procedures for aircraft safety benefit birds through a reduction in the potential for aircraft strike.

2.3.3.4 High-Energy Laser Safety

The Navy operates laser systems approved for fielding by the Laser Safety Review Board or service equivalent. Only properly trained and authorized personnel operate high-energy lasers within designated OPAREAS and ranges. OPAREAS and ranges where lasers are used are required to have a Laser Range Safety Certification Report that is updated every three years. Prior to commencing activities involving high-energy lasers, the operator performs a search of the intended impact location to ensure that the area is clear of unauthorized persons. These standard operating procedures benefit public health and safety through a reduction in the potential for interaction with high-energy lasers.

2.3.3.5 Weapons Firing Safety

A Notice to Mariners is issued in advance of gunnery activities to alert the public to stay clear of the area, except for small-caliber crew-served weapons training when the immediate area around the firing ship is cleared visually. Locations where explosive bombing activities occur often have a standing Notice to Mariners. Notices to Mariners are issued in advance of explosive bombing activities conducted in locations that do not already have a standing notice. Additional information on Notices to Mariners is provided in Section 3.12.2.1.1 (Sea Space).

Most weapons firing activities that involve the use of explosive munitions are conducted during daylight hours. All missile and rocket firing activities are carefully planned in advance and conducted under strict procedures that place the ultimate responsibility for range safety on the Officer Conducting the Exercise or civilian equivalent. The weapons firing hazard range must be clear of non-participating vessels and aircraft before firing activities commence. The size of the firing hazard range is based on the farthest firing range capability of the weapon being used. All weapons firing stops when the Range Safety Officer receives a cease-fire order or when the line of fire could endanger non-participating vessels or aircraft. Pilots of Navy aircraft are not authorized to expend munitions, fire missiles, or drop other airborne devices through extensive cloud cover where visual clearance for non-participating aircraft and vessels is not possible. The two exceptions to this requirement are: (1) when operating in the open ocean, clearance for non-participating aircraft and vessels through radar surveillance is acceptable; and (2) when the Officer Conducting the Exercise or civilian equivalent accepts responsibility for the safeguarding of airborne and surface traffic. These standard operating procedures benefit public health and safety, and marine mammals and sea turtles (by increasing the effectiveness of visual observations for mitigation in daylight hours), through a reduction in the potential for interaction with explosive weapons firing activities.

During activities that involve recoverable targets (e.g., aerial drones), the Navy recovers the target and any associated decelerators/parachutes to the maximum extent practicable consistent with personnel and equipment safety. Recovery of these items helps minimize materials that remain, which could potentially alert enemy forces to the presence of U.S. Navy assets during military missions and combat operations. This standard operating procedure benefits biological resources (e.g., marine mammals, sea turtles, fish) through a reduction in the potential for physical disturbance and strike, entanglement, and ingestion of applicable targets and any associated decelerators/parachutes. Additional information about military expended materials (including which are recoverable) is presented in Section 3.0.3.3.4.2 (Military Expended Materials) and Appendix F (Military Expended Material and Direct Strike Impact Analyses).

2.3.3.6 Target Deployment and Retrieval Safety

The deployment and retrieval of targets is dependent upon environmental conditions. The Beaufort sea state scale is a standardized measurement of the weather conditions, based primarily on wind speed. The scale is divided into levels from 0 to 12, with 12 indicating the most severe weather conditions (e.g., hurricane force winds). At Beaufort sea state number 4, wave heights typically range from 3.5 to 5 ft. Firing exercises involving the deployment and retrieval of targets from small boats are typically conducted in daylight hours in Beaufort sea state number 4 conditions or better to ensure safe operating conditions during target deployment and recovery. These standard operating procedures benefit public health and safety, and marine mammals and sea turtles (by increasing the effectiveness of visual observations for mitigation), through a reduction in the potential for interaction with the weapons firing activities associated with the use of applicable deployed targets.

2.3.3.7 Swimmer Defense Activity Safety

A Notice to Mariners is issued in advance of all swimmer defense activities. Additional information on Notices to Mariners is provided in Section 3.12.2.1.1 (Sea Space). A daily in situ calibration of sound source levels is used to establish a clearance area to the 145 decibels referenced to 1 micropascal (dB re 1 µPa) sound pressure level threshold for non-participant safety. A hydrophone is used during the calibration sequences in order to confirm the clearance area. Small boats patrol the 145 dB re 1 µPa sound pressure level area during all activities. Boat crews are equipped with binoculars and remain vigilant for non-participant boats, swimmers, snorkelers, divers, and dive flags. If a non-participating swimmer, snorkeler, or diver is observed entering into the area of the swimmer defense system, the power levels of the defense system are reduced. An additional 100-yard buffer is applied to the initial sighting location of the non-participant as an additional precaution, and this buffer area is used to determine if the non-participant is within the 145 dB re 1 µPa zone. If the area cannot be maintained free of non-participating swimmers, snorkelers, and divers, the activity will cease until the non-participant has moved outside the area. These standard operating procedures benefit public health and safety (including persons participating in activities that have socioeconomic value, such as recreational diving) through a reduction in the potential for interaction with swimmer defense activities.

2.3.3.8 Pierside Testing Safety

The *U.S. Navy Dive Manual* (U.S. Department of the Navy, 2011) prescribes safe distances for divers from active sonar sources and in-water explosions. Safety distances for the use of electromagnetic energy are specified in DoD Instruction 6055.11 (U.S. Department of Defense, 2009) and Military Standard 464A (U.S. Department of Defense, 2002). These distances are used as the standard safety buffers for in-water energy to protect Navy divers. If an unauthorized person is detected within the exercise area, the activity will be temporarily halted until the area is again cleared and secured. These standard operating procedures benefit public health and safety (including persons participating in activities that have socioeconomic value, such as commercial or recreational diving) through a reduction in the potential for interaction with pierside testing activities.

2.3.3.9 Underwater Detonation Safety

Underwater detonation training takes place in designated areas that are located away from popular recreational dive sites, primarily for human safety. Recreational dive sites oftentimes include shallow-water coral reefs, artificial reefs, and wrecks. If an unauthorized person (e.g., a recreational diver) is detected within the exercise area, the activity will be temporarily halted until the area is cleared and secured. Notices to Mariners are issued when the events are scheduled to alert the public to stay clear of the area. Additional information on Notices to Mariners is provided in Section 3.12.2.1.1 (Sea Space). These standard operating procedures benefit public health and safety, environmental resources (e.g., shallow-water coral reefs, artificial reefs, and the biological resources that inhabit, shelter in, or feed among them), and cultural resources through a reduction in the potential for interaction with underwater detonation activities.

2.3.3.10 Sonic Booms

As a general policy, aircraft do not intentionally generate sonic booms below 30,000 ft. of altitude unless over water and more than 30 mi. from inhabited land areas or islands. The Navy may authorize deviations from this policy for tactical mission, phases of formal training syllabus flights, or research, test, and operational suitability test flights. The standard operating procedures for sonic booms benefit public health and safety through a reduction in the potential for exposure to sonic booms.

2.3.3.11 Unmanned Aerial System, Surface Vehicle, and Underwater Vehicle Safety

For activities involving unmanned aerial systems, surface vehicles, or underwater vehicles, the Navy evaluates the need to publish a Notice to Airmen or Notice to Mariners based on the scale, location, and timing of the activity. When necessary, Notices to Airmen and Notices to Mariners are issued to alert the public to stay clear of the area. Additional information is provided on Notices to Mariners in Section 3.12.2.1.1 (Sea Space) and Notices to Airmen in Section 3.12.2.1.2 (Airspace). Unmanned aerial systems are operated in accordance with Federal Aviation Administration air traffic organization policy as specified in Office of the Chief of Naval Operations Instructions 3710, 3750, and 4790. These standard operating procedures benefit public health and safety through a reduction in the potential for interaction with these unmanned systems and vehicles.

2.3.3.12 Towed In-Water Device Safety

As a standard collision avoidance procedure, prior to deploying a towed in-water device from a manned platform, the Navy searches the intended path of the device for any floating debris, objects, or animals (e.g., driftwood, concentrations of floating vegetation, marine mammals) that have the potential to obstruct or damage the device. This standard operating procedure benefits marine mammals, sea turtles, and vegetation through a reduction in the potential for physical disturbance and strike by a towed in-water device. Concentrations of floating vegetation can be indicators of potential marine mammal or sea turtle presence because marine mammals and sea turtles have been known to seek shelter in, feed on, or feed among them. For example, young sea turtles have been known to hide from predators and eat the algae associated with floating concentrations of *Sargassum*.

2.3.3.13 Pile Driving Safety

Due to pile driving system design and operation, the Navy performs soft starts during impact installation of each pile to ensure proper operation of the diesel impact hammer. During a soft start, the Navy performs an initial set of strikes from the impact hammer at reduced energy before it can be operated at full power and speed. The energy reduction of an individual hammer cannot be quantified because it varies by individual driver. The number of strikes at reduced energy varies because raising the hammer at less than full power and then releasing it results in the hammer “bouncing” as it strikes the pile, which results in multiple “strikes.” This standard operating procedure benefits marine mammals, sea turtles, and fish because soft starts may “warn” these resources and cause them to move away from the sound source before impact pile driving increases to full operating capacity.

2.3.3.14 Sinking Exercise Safety

The Navy is required to conduct sinking exercises greater than 50 NM from land and in waters at least 6,000 ft. deep (40 CFR section 229.2). The Navy selects sinking exercise areas to avoid established commercial air traffic routes, commercial vessel shipping lanes, and areas used for recreational activities, and to allow for the necessary separation of Navy units to ensure safety of Navy personnel, the public, commercial aircraft and vessels, and Navy assets. These standard operating procedures benefit public health and safety (including persons participating in activities that have socioeconomic value, such as recreational or commercial fishing) through a reduction in the potential for interaction with sinking exercises.

2.3.4 Mitigation Measures

The Navy will implement mitigation measures to avoid or reduce potential impacts from the Proposed Action on environmental and cultural resources, some of which have a high socioeconomic value in the Study Area. Mitigation measures that the Navy will implement under the Proposed Action are organized into two categories: procedural mitigation measures and mitigation areas. The Navy will implement procedural mitigation measures whenever and wherever applicable training or testing activities take place within the Study Area. Mitigation areas are geographic locations within the Study Area where the Navy will implement additional mitigation during all or part of the year.

A list of the activity categories, stressors, and geographic locations that have mitigation measures is provided in Table 2.3-7. Chapter 5 (Mitigation) and Appendix K (Geographic Mitigation Assessment) provide a full description of each mitigation measure that will be implemented under the Proposed Action, including a discussion of how the Navy developed and assessed each measure and detailed maps of the mitigation area locations. Relevant mitigation details are also provided throughout Appendix A

(Navy Activity Descriptions). The Navy and NMFS Records of Decision, MMPA Regulations and Letters of Authorization, and Endangered Species Act (ESA) Biological Opinions will document all mitigation measures that the Navy will implement under the Proposed Action.

Table 2.3-7: Overview of Mitigation Categories

Mitigation Category	*Chapter 5 (Mitigation) Section*	*Applicable Activity Category, Stressor, or Mitigation Area Location*
Procedural Mitigation	Section 5.3.2 (Acoustic Stressors)	Active Sonar Air Guns Pile Driving Weapons Firing Noise
	Section 5.3.3 (Explosive Stressors)	Explosive Sonobuoys Explosive Torpedoes Explosive Medium-Caliber and Large-Caliber Projectiles Explosive Missiles and Rockets Explosive Bombs Sinking Exercises Explosive Mine Countermeasure and Neutralization Activities Explosive Mine Neutralization Activities Involving Navy Divers Underwater Demolition Multiple Charge – Mat Weave and Obstacle Loading Maritime Security Operations – Anti-Swimmer Grenades
	Section 5.3.4 (Physical Disturbance and Strike Stressors)	Vessel Movement Towed In-Water Devices Small-, Medium-, and Large-Caliber Non-Explosive Practice Munitions Non-Explosive Missiles and Rockets Non-Explosive Bombs and Mine Shapes
Mitigation Areas	Section 5.4 (Mitigation Areas to be Implemented)	Areas with Seafloor Resources Hawaii Island Mitigation Area 4-Islands Region Mitigation Area Humpback Whale Special Reporting Areas San Diego Arc, San Nicolas Island, and Santa Monica/Long Beach Mitigation Areas Santa Barbara Island Mitigation Area Awareness Notification Message Areas for Large Whales

2.4 ACTION ALTERNATIVE DEVELOPMENT

The identification, consideration, and analysis of alternatives are critical components of the NEPA process and contribute to the goal of objective decision-making. The Council on Environmental Quality issued regulations implementing the NEPA, and these regulations require the decision maker to consider the environmental effects of the proposed action and a range of alternatives (including the no action alternative) to the proposed action (40 CFR section 1502.14). Council on Environmental Quality regulations further provide that an EIS must rigorously explore and objectively evaluate all reasonable alternatives for implementing the proposed action, and for alternatives eliminated from detailed study, briefly discuss the reasons for their having been eliminated. To be reasonable, an alternative, except for the no action alternative, must meet the stated purpose of and need for the proposed action. An alternative that does not meet the stated purpose of and need for the proposed action is not considered reasonable.

The Action Alternatives, and in particular the mitigation measures that are incorporated in the Action Alternatives, were developed to meet both the Navy's purpose and need to train and test, and NMFS's independent purpose and need to evaluate the potential impacts of the Navy's activities, determine whether incidental take resulting from the Navy's activities will have a negligible impact on affected marine mammal species and stocks, and to prescribe measures to effect the least practicable adverse impact on species or stocks and their habitat, as well as monitoring and reporting requirements.

The Navy developed the alternatives considered in this EIS/OEIS after careful assessment by subject matter experts, including military commands that utilize the ranges, military range management professionals, and Navy environmental managers and scientists. The Navy also used new or updated military policy and historical data in developing alternatives.

For example, one military policy used to inform the alternatives development was the Optimized Fleet Response Plan, discussed in Section 1.4.2 (Optimized Fleet Response Plan), which changed how the Navy meets its readiness requirements. The data developed from the Optimized Fleet Response Plan informs the level of training, including the use of sonar sources and explosives, required by the Navy to meet its Title 10 responsibilities, which mandates to organize, train, and equip combat ready forces (10 U.S.C. section 5062). Additionally, during prior phases of comprehensive environmental planning, the Navy assumed that all unit-level sonar training requirements were met through independent training events, meaning each active sonar training requirement was analyzed as a discrete event. This was done for two reasons. First, there was insufficient data to determine if training requirements were being met through means other than live at-sea training, such as through the use of simulated training. Second, since this data was unavailable during prior phases of environmental planning, the Navy wanted to ensure it did not underestimate the potential effects of these activities when seeking MMPA/ESA permits, resulting in permits with insufficient authority to support the Navy's requirements. This could have resulted in the possibility of exceeding permit limits and resulted in non-compliance with the law.

Through the collection of several years of classified sonar use data, the Navy produced a more refined analysis of the amount of sonar usage that the Navy anticipates will be necessary to meet its training and testing requirements, which underlie the development of the action alternatives.

With regards to testing activities, as previously stated, the level of activity in any given year is highly variable and is dependent on technological advancements, emergent requirements identified during operations, and fiscal fluctuations. Therefore, the environmental analysis must consider all testing activities that could possibly occur to ensure that the analysis fully captures the potential environmental effects. These factors were considered in alternatives carried forward for consideration and analyses as described in Section 2.5 (Alternatives Carried Forward).

2.4.1 TRAINING

The analysis of sonar use showed that ships are meeting their active sonar training requirements through a variety of methods. Ships are limited in the number of underway days that are available to conduct at-sea training during the training cycle due to training schedules and constrained fuel resources. Sailors are required to conduct a variety of unit-level training events, throughout all training phases to maintain readiness and conduct this training through a variety of methods, including simulators, unit-level live training at sea, and unit-level training accomplished in conjunction with other training exercises.

Simulators are best used to develop operator efficiency, but they can also be used to train watch teams. While this does build proficiency, it cannot replicate the real-world complexities Sailors will have to deal with while deployed. Operating active sonar in the ocean is extremely complex due to numerous environmental factors that affect how sound travels through water, which cannot be realistically replicated. Only by training in the actual ocean environment can ship crews learn how to deal with these rapidly changing parameters and optimize their sensors to locate underwater objects such as submarines and mines. In summary, while simulators are an important tool for attaining and maintaining readiness, they cannot completely replace live training at sea.

To maximize training effectiveness during limited at-sea opportunities, the Navy takes advantage of training events that can meet multiple training requirements. For example, during an integrated or major training exercise that tracks a submarine with active sonar, units can also satisfy unit-level training requirement to maintain proficiency in tracking submarines with active sonar. In previous environmental analyses, the Navy assumed that each requirement was met through independent training events. However, Navy's analysis has found that, in some instances, multiple requirements (i.e., unit-level, integrated, and major training requirements) could be met during one activity. This ability to meet multiple requirements during one activity effectively reduces the number of times the activity needs to be conducted and, therefore, the sound energy transmitted into the water.

The Optimized Fleet Response Plan also influences the amount of active sonar transmitted during training. Under the prior Fleet Response Plan, as discussed in Section 1.4.2 (Optimized Fleet Response Plan), the Navy was required to be prepared to deploy eight carrier strike groups within six months. This meant that Navy units had to accomplish all training requirements from the basic phase through the integrated phase in a six-month period. Although this level of training would occur if the Navy had to respond to a major national security crisis, this level of training has not been conducted in recent years. Instead, the Navy has been responding to significant but more regional challenges through scheduled deployments while still maintaining a stabilizing and continuous presence around the globe. From an environmental planning and permitting perspective, the combination of analyzing a year where world events require certification and deployment of eight carrier strike groups and repeating the maximum certification and deployment requirement every year resulted in Navy's analyses and permits overestimating the number of training requirements. This also then overestimated the potential effects of that training over the 5-year MMPA incidental take authorization period. Up until this point, the current force structure (the number of ships, submarines, and aircraft), has resulted in significantly less active sonar use than what was analyzed in the previous environmental planning compliance documents, and as reflected in the 2013–2018 permits. The Navy considered this data in developing the action alternatives.

2.4.2 Testing

As described in Section 1.4.3 (Why the Navy Tests), there are multiple factors that make it challenging for the Navy to accurately predict future testing requirements. Testing conducted on past systems is not a reliable predictor of future testing duration and tempo, since testing requirements and funding can change. Also, testing of a given system does not occur on a predictable annual cycle but rather in discrete test phases that differ in duration and frequency. Some test phases are relatively short, up to a year, while others can take multiple years. The duration and timing of testing will vary depending on federal funding cycles and the success of past test events. The time, place, and details of future testing depend on scientific developments that are not easy to predict, and experimental designs may evolve with emerging science and technology. Even with these challenges, the Navy makes every effort to accurately forecast all future testing requirements.

In order to adequately support Navy testing requirements that are driven by the need to support fleet readiness, alternatives must have an annual capacity to conduct the research, development, and testing to support the following:

- new systems and new technologies,
- upgrades to existing systems,
- testing of existing systems after repair and maintenance activities, and
- lot acceptance testing of systems.

Depending on emerging national security interests or threats to U.S. forces, the Navy may begin rapid development projects that were unanticipated at the time of initial environmental planning. Additionally, the potential that naval forces may need to quickly respond to world conflict or evolving threats may mean that sometimes technical evaluation and operational evaluation of a system could be expedited and occur in the same year. Therefore, the planning for future testing must accommodate these emergent requirements as much as possible. Based on these many uncertainties, the Navy's projected testing requirements and requested authorizations for testing within the HSTT Study Area provides the Navy the ability to test to a potential foreseeable annual maximum level. The maximum level is used in the analysis and authorization to ensure that Navy does not underestimate the potential impacts during the analysis. Consequently, Navy testing during any given year of an authorization timeframe can be less than the levels analyzed.

2.4.3 Alternatives Eliminated from Further Consideration

Alternatives eliminated from further consideration are described below. The Navy determined that these alternatives did not meet the purpose of and need for the Proposed Action after a thorough consideration of each.

2.4.3.1 Alternative Training and Testing Locations

Navy ranges have evolved over the decades and, considered together, allow for the entire spectrum of training and testing to occur in a given range complex. While some unit-level training and some testing activities may require only one training element (airspace, sea surface space, or undersea space), more advanced training and testing events may require a combination of air, surface, and undersea space as well as access to land ranges. The ability to utilize the diverse and multi-dimensional capabilities of each range complex or testing range allows the Navy to develop and maintain high levels of readiness. The Study Area and the range complexes and testing ranges it contains have attributes necessary to support effective training and testing. No other locations match the Study Area attributes, which are as follows:

- proximity to the homeport regions of San Diego and Hawaii, and the Navy commands, ships, submarines, schools, and aircraft units and Marine Corps forces stationed there
- proximity to shore-based facilities and infrastructure, and the logistical support provided for training and testing activities
- proximity to military families, minimizing the length of time Sailors and Marines spend deployed away from home and benefitting overall readiness
- presence of unique ranges, which include instrumented deep and shallow ranges in Hawaii and Southern California that offer training and testing capabilities not available elsewhere in the Pacific, and ranges that offer both actual and simulated shore gunnery training for Navy ships

- environmental conditions (e.g., bathymetry, topography, and weather) found in the Study Area that maximize the training realism and testing effectiveness

The uniquely interrelated nature of the features and attributes of the range complexes located within the Study Area (as detailed in Section 2.1, Description of the Hawaii-Southern California Training and Testing Study Area) provides the training and testing support needed for complex military activities. There is no other series of integrated ranges in the Pacific Ocean that affords this level of operational support and comprehensive integration for range activities. There are no other potential locations in the Pacific where land ranges, OPAREAs, undersea terrain and ranges, and military airspace combine to provide the venues necessary for the training and testing realism and effectiveness required to train and certify naval forces for combat operations.

2.4.3.2 Simulated Training and Testing Only

The Navy currently uses simulation for training and testing whenever possible (e.g., command and control exercises are conducted without operational forces); however, there are significant limitations, and its use cannot replace live training or testing.

To detect and counter mine shapes and hostile submarines, the Navy uses both passive and active sonar. Sonar proficiency is a complex and perishable skill that requires regular, hands-on training in realistic and diverse conditions. More than 300 extremely quiet, newer-generation submarines are operated by more than 40 nations worldwide, and these numbers are growing. These difficult-to-detect submarines, as well as torpedoes and underwater mines, are true threats to global commerce, national security, and the safety of military personnel. As a result, defense against enemy submarines is a top priority for the Navy. Anti-submarine warfare training and testing activities include the use of active and passive sonar systems and small explosive charges, which prepare and equip Sailors for countering threats. Inability to train with sonar would eliminate or diminish anti-submarine warfare readiness. Failure to detect and defend against hostile submarines can cost lives, such as the 46 Sailors who lost their lives when a Republic of Korea frigate (CHEONAN) was sunk by a North Korean submarine in March 2010.

There are limits to the realism that current simulation technology can presently provide. Unlike live training, today's simulation technology does not permit anti-submarine warfare training with the degree of realism and complexity required to maintain proficiency. While simulators are used for the basic training of sonar technicians, they are of limited value beyond basic training. A simulator cannot match the dynamic nature of the environment, such as bathymetry and sound propagation properties, or the training activities involving several units with multiple crews interacting in a variety of acoustic environments.

Sonar operators must train regularly and frequently to develop and maintain the skills necessary to master the process of identifying underwater threats in the complex subsurface environment. Sole reliance on simulation would deny service members the ability to develop battle-ready proficiency in the employment of active sonar in the following areas:

- Bottom bounce and other environmental conditions. Sound hitting the ocean floor (bottom bounce) reacts differently depending on the bottom type and depth. Likewise sound passing through changing currents, eddies, or across differences in ocean temperature, pressure, or salinity is also affected. Both of these are extremely complex and difficult to simulate, and both are common in actual sonar operations.

- Mutual sonar interference. When multiple sonar sources are operating in the vicinity of each other, interference due to similarities in frequency can occur. Again, this is a complex variable that must be recognized by sonar operators, but is difficult to simulate with any degree of fidelity.
- Interplay between ship and submarine target. Ship crews, from the sonar operator to the ship's Captain, must react to the changing tactical situation with a real, thinking adversary (a Navy submarine for training purposes). Training in actual conditions with actual submarine targets provides a challenge that cannot be duplicated through simulation.
- Interplay between anti-submarine warfare teams in the strike group. Similar to the interplay required between ships and submarine targets, a ship's crew must react to all changes in the tactical situation, including changes from cooperating ships, submarines, and aircraft.

Similar to the challenges presented in the training situations above, operational testing cannot be based exclusively on computer modeling or simulation either (see 10 U.S.C. sections 2366 and 2399). At-sea testing provides the critical information on operability and supportability needed by the Navy to make decisions on the procurement of platforms and systems, ensuring that what is purchased performs as expected and that tax dollars are not wasted. Meeting this testing requirement is also critical to protecting the Sailors and Marines who depend on these technologies to execute their mission with minimal risk to themselves.

As the acquisition authority for the Navy, the Systems Commands are responsible for administering large contracts for the Navy's procurement of platforms and systems. These contracts include performance criteria and specifications that must be verified to ensure that the Navy accepts platforms and systems that support the warfighter's needs. Although simulation is a key component in platform and systems development, it does not adequately provide information on how a system will perform or whether it will be available to meet performance and other specification requirements because of the complexity of the technologies in development and marine environments in which they will operate. For this reason, at some point in the development process, platforms and systems must undergo at-sea or in-flight testing. Therefore, simulation as an alternative that replaces training and testing in the field does not meet the purpose of and need for the Proposed Action and has been eliminated from detailed study.

2.4.3.3 Training and Testing Without the Use of Active Sonar

As explained in Section 2.4.3.2 (Simulated Training and Testing Only), in order to detect and counter submerged mines and hostile submarines, the Navy uses both passive and active sonar. Sonar proficiency is a complex and perishable skill that requires regular, hands-on training in realistic and diverse conditions. Active sonar is needed to find and counter newer-generation submarines around the world, which are growing in number, as are torpedoes and underwater mines, which are true threats to global commerce, national security, and the safety of military personnel. As a result, defense against enemy submarines is a top priority for the Navy.

2.4.3.4 Alternatives Including Geographic Mitigation Measures Within the Study Area

The Navy considered developing an alternative based solely on geographic mitigation, such that time/area restrictions would be imposed within a single alternative. NEPA identifies the application of mitigation measures to the alternatives "when not already included in the proposed action or alternatives" (40 CFR 1502.14). The Navy's alternatives were developed in order to satisfy the purpose and need related to fulfilling its Title 10 requirements. Under both alternatives, the Navy would implement mitigation measures (including geographic mitigation areas that are biologically supported and practicable to implement) as described in Chapter 5 (Mitigation) and Appendix K (Geographic Mitigation Assessment). Therefore, the mitigation would be implemented regardless of which alternative is selected.

2.5 ALTERNATIVES CARRIED FORWARD

The Navy's anticipated level of training and testing activity evolves over time based on numerous factors as discussed in the preceding paragraphs in Section 2.4 (Action Alternative Development). Additionally, over the past several years, the Navy's ongoing sonar reporting program has gathered classified data regarding the number of hull-mounted mid-frequency sonar hours used to meet anti-submarine warfare requirements, which has increased understanding of how sonar training hours are generated. This data allows for a more accurate projection of the number of active sonar hours required to meet anti-submarine warfare training requirements into the reasonably foreseeable future.

In light of this information, the Navy was able to better formulate a range of reasonable alternatives that meet Navy training requirements while reflecting a lower, and more realistic, impact on the environment. This analysis of ongoing activities also provides a more accurate assessment of the Navy's current impact on the environment from ongoing Navy training and testing when compared to the currently permitted activities.

As previously discussed, in addition to meeting Navy's purpose and need to train and test, the Action Alternatives, and in particular the mitigation measures that are incorporated in the Action Alternatives, were developed to meet NMFS's independent purpose and need to evaluate the potential impacts of the Navy's activities; determine whether incidental take resulting from the Navy's activities will have a negligible impact on affected marine mammal species and stocks; and prescribe measures to effect the least practicable adverse impact on species or stocks and their habitat, as well as monitoring and reporting requirements.

2.5.1 NO ACTION ALTERNATIVE

As mentioned above in Section 2.4 (Action Alternative Development), the Council on Environmental Quality implementing regulations require inclusion of a No Action Alternative and analysis of all reasonable alternatives to provide a clear basis for choice among options by the decision maker and the public (40 CFR section 1502.14). Council on Environmental Quality guidance identifies two approaches in developing the No Action Alternative (46 *Federal Register* 18026). One approach for activities that have been ongoing for long periods of time is for the No Action Alternative to be thought of in terms of continuing the present course of action, or current management direction or intensity, such as the continuation of Navy training and testing at sea in the HSTT Study Area at current levels, even if separate legal authorizations under the MMPA and ESA are required. Under this approach, which was used in Phases I and II of the Navy's environmental planning and compliance program for training and testing activities at sea, the analysis compares the effects of continuing current activity levels (i.e., the "status quo") with the effects of the Proposed Action. The second approach depicts a scenario where no authorizations or permits are issued, the Navy's training and testing activities do not take place, and the resulting environmental effects from taking no action are compared with the effects of the Proposed Action. This approach is being applied in Phase III of the Navy's environmental planning and compliance program, including in this EIS/OEIS.

Under the No Action Alternative analyzed in this EIS/OEIS, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Consequently, the No Action Alternative of not conducting the proposed live, at-sea training and testing in the HSTT Study Area is inherently unreasonable in that it does not meet the Navy's purpose and need (see Section 1.4, Purpose and Need for Proposed Military Readiness Training and Testing Activities) for the reasons noted in the next four paragraphs. However, the analysis associated with the No Action Alternative is carried forward in order to compare the magnitude of the potential environmental effects of the Proposed Action with the conditions that would occur if the Proposed Action did not occur (see Section 3.0, Introduction).

From NMFS' perspective, pursuant to its obligation to grant or deny permit applications under the MMPA, the No Action Alternative involves NMFS denying Navy's application for an incidental take authorization under section 101(a)(5)(A) of the MMPA. If NMFS were to deny the Navy's application, the Navy would not be authorized to incidentally take marine mammals in the HSTT Study Area, and under the No Action Alternative, as explained above, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area.

Cessation of proposed Navy at-sea training and testing activities would mean that the Navy would not meet its statutory requirements and would be unable to properly defend itself and the United States from enemy forces, unable to successfully detect enemy submarines, and unable to effectively use its weapons systems or defensive countermeasures. Navy personnel would essentially not be taught how to use Navy systems in any realistic scenario. For example, sonar proficiency, which is a complex and perishable skill, requires regular, hands-on training in realistic and diverse conditions. In order to detect and counter hostile submarines, the Navy uses both passive and active sonar. Inability to train with active sonar would result in no or greatly diminished anti-submarine warfare capability.

Additionally, without proper training, individual Sailors and Marines serving onboard Navy vessels would not be taught how to properly operate complex equipment in inherently dynamic and dangerous environments. Thus, even during routine non-combat operations, it is likely that there would be an increase in the number of mishaps, potentially resulting in the death or serious injury of Sailors and Marines. Failing to allow our Sailors and Marines to achieve and maintain the skills necessary to defend the United States and its interests will result in an unacceptable increase in the danger they willingly face.

Finally, the lack of live training and testing would require a higher reliance on simulated training and testing. While the Navy continues to research new ways to provide realistic training through simulation, there are limits to the realism that current technology can presently provide. While simulators are used for the basic training of sonar technicians, they are of limited utility beyond basic training. A simulator cannot match the dynamic nature of the environment, such as bathymetry and sound propagation properties, or the training activities involving several units with multiple crews interacting in a variety of acoustic environments. Sole reliance on simulation would deny service members the ability to develop battle-ready proficiency in the employment of active sonar (Section 2.4.3.2, Simulated Training and Testing Only).

2.5.2 Alternative 1

Alternative 1 is the Preferred Alternative.

2.5.2.1 Training

Under this alternative, the Navy proposes to conduct military readiness training activities into the reasonably foreseeable future, as necessary to meet current and future readiness requirements. These military readiness training activities include new activities as well as activities subject to previous analysis that are currently ongoing and have historically occurred in the Study Area. The requirements for the types of activities to be conducted, as well as the intensity at which they need to occur, have been validated by senior Navy leadership. Specifically, training activities are based on the requirements of the Optimized Fleet Response Plan and on changing world events, advances in technology, and Navy tactical and strategic priorities. These activities account for force structure changes and include training with new aircraft, vessels, unmanned/autonomous systems, and weapon systems that will be introduced to the fleets after December 2018. The numbers and locations of all proposed training activities are provided in Section 2.6.1 (Proposed Training Activities).

Alternative 1 reflects a representative year of training to account for the natural fluctuation of training cycles and deployment schedules that generally limit the maximum level of training from occurring year after year in any 5-year period. Using a representative level of activity rather than a maximum tempo of training activity in every year has reduced the amount of hull-mounted mid-frequency active sonar estimated to be necessary to meet training requirements. Both unit-level training and major training exercises are adjusted to meet this representative year, as discussed below.

Under Alternative 1, the Navy assumes that some unit-level training would be conducted using synthetic means (e.g., simulators). Additionally, this alternative assumes that some unit-level active sonar training will be completed through other training exercises. By using a representative level of training activity rather than a maximum level of training activity in every year, this alternative accepts a degree of risk that if global events necessitated a rapid expansion of military training that the Navy would not have sufficient capacity in its MMPA and ESA authorizations to carry out those training requirements.

The Optimized Fleet Response Plan and various training plans identify the number and duration of training cycles that could occur over a 5-year period. Alternative 1 considers fluctuations in training cycles and deployment schedules that do not follow a traditional annual calendar but instead are influenced by in-theater demands and other external factors. This alternative takes a similar approach to estimating levels of some of the larger training exercises as it does for unit-level training. Specifically, this alternative does not analyze a maximum number of carrier strike group Composite Training Unit Exercises (one type of major exercise) every year, but instead assumes a maximum number of exercises would occur during two years of any 5-year period. As a result, Alternative 1 will analyze a maximum of 3 Composite Training Unit Exercises (and certain other coordinated events leading up to a Composite Training Unit Exercise) in any given year and not more than 12 over any 5-year period.

The Sinking Exercise requirement in this alternative has been reduced from the 40 Sinking Exercises that were analyzed and permitted over five years in Phase II to 8 over the 5-year period to reflect typical past Sinking Exercise execution.

This alternative incorporates a degree of risk that the Navy will not have sufficient capacity in potential MMPA and ESA authorizations to support the full spectrum of training potentially necessary to respond to a future national emergency crisis.

This risk associated with the preferred alternative was deemed acceptable by Commander, Pacific Fleet based on training requirements needed to meet the current world geo-political environment. The acceptance of this risk was contingent on a thorough analysis of Alternative 2, including annual maximum levels of unit-level active sonar hours and Composite Training Unit Exercises using the best available science.

2.5.2.2 Testing

Alternative 1 reflects a level of testing activities to be conducted into the reasonably foreseeable future, with adjustments that account for changes in the types and tempo (increases or decreases) of testing activities to meet current and future military readiness requirements. This alternative includes the testing of new platforms, systems, and related equipment that will be introduced after December 2018. The majority of testing activities that would be conducted under this alternative are the same as or similar as those conducted currently or in the past. This alternative includes the testing of some new systems using new technologies and takes into account inherent uncertainties in this type of testing.

Under Alternative 1, the Navy proposes an annual level of testing that reflects the fluctuations in testing programs by recognizing that the maximum level of testing will not be conducted each year. This alternative contains a more representative level of activities, but includes years of a higher maximum amount of testing to account for these fluctuations. This alternative would not include the contingency for augmenting some weapon system tests, which would increase levels of annual testing of anti-submarine warfare and mine warfare systems, and presumes a typical level of readiness requirements. The numbers and locations of all proposed testing activities are listed in Table 2.6-2 through Table 2.6-5.

2.5.2.3 Mitigation Measures

The Navy's entire suite of mitigation measures was applied to Alternative 1 to ensure that: (1) the benefit of mitigation measures to environmental and cultural resources was considered during the applicable environmental analyses, and (2) Navy Senior Leadership approved each mitigation measure that would be implemented under Alternative 1. Navy Senior Leadership reviewed relevant supporting information to make a fully informed decision, including the benefit of mitigation measures to environmental and cultural resources, and the impacts that implementing mitigation will have on training and testing activities under Alternative 1. As discussed in Chapter 5 (Mitigation), the mitigation measures represent the maximum level of mitigation that is practicable for the Navy to implement when balanced against impacts to safety, sustainability, and the ability to continue meeting its mission requirements.

2.5.3 Alternative 2

2.5.3.1 Training

As under Alternative 1, this alternative includes new and ongoing activities. Under Alternative 2, training activities are based on requirements established by the Optimized Fleet Response Plan. Under this alternative, the Navy would be enabled to meet the highest levels of required military readiness by conducting the majority of its training live at sea, and by meeting unit-level training requirements using dedicated, discrete training events, instead of combining them with other training activities as described in Alternative 1. The numbers and locations of all proposed training activities are provided in Table 2.6-1.

Alternative 2 reflects the maximum number of training activities that could occur within a given year, and assumes that the maximum level of activity would occur every year over any 5-year period. This allows for the greatest flexibility for the Navy to maintain readiness when considering potential changes in the national security environment, fluctuations in training and deployment schedules, and anticipated in-theater demands. Both unit-level training and major training exercises are assumed to occur at a maximum level every year.

For Phase III, Alternative 2 reduces the total number of Composite Training Unit Exercises to 15 for the Southern California portion of the HSTT Study Area, over any 5-year period.

The sinking exercise requirement has been reduced from the 40 Sinking Exercises that were analyzed and permitted over five years in Phase II to 20 Sinking Exercises over any 5-year period that will be analyzed and permitted in Phase III. This reflects the maximum number of Sinking Exercises due to the limited availability of Sinking Exercise targets.

2.5.3.2 Testing

Like Alternative 1, Alternative 2 entails a level of testing activities to be conducted into the reasonably foreseeable future and includes the testing of new platforms, systems, and related equipment that will be introduced after December 2018. The majority of testing activities that would be conducted under this alternative are the same as or similar as those conducted currently or in the past.

Alternative 2 would include the testing of some new systems using new technologies, taking into account the potential for delayed or accelerated testing schedules, variations in funding availability, and innovations in technology development. To account for these inherent uncertainties in testing, this alternative assumes that the maximum annual testing efforts predicted for each individual system or program could occur concurrently in any given year. This alternative also includes the contingency for augmenting some weapon systems tests in response to potential increased world conflicts and changing Navy leadership priorities as the result of a direct challenge from a naval opponent that possesses near-peer capabilities. Therefore, this alternative includes the provision for higher levels of annual testing of certain anti-submarine warfare and mine warfare systems to support expedited delivery of these systems to the fleet. All proposed testing activities are listed in Table 2.6-2 through Table 2.6-5.

2.5.3.3 Mitigation Measures

The Navy's entire suite of mitigation measures was applied to Alternative 2 to ensure that: (1) the benefit of mitigation measures to environmental and cultural resources was considered during the applicable environmental analyses, and (2) Navy Senior Leadership approved each mitigation measure that would be implemented under Alternative 2. Navy Senior Leadership reviewed relevant supporting information to make a fully informed decision, including the benefit of mitigation measures to environmental and cultural resources, and the impacts that implementing mitigation will have on training and testing activities under Alternative 2. As discussed in Chapter 5 (Mitigation), the mitigation measures represent the maximum level of mitigation that is practicable for the Navy to implement when balanced against impacts to safety, sustainability, and the ability to continue meeting its mission requirements.

2.5.4 Comparison of Proposed Sonar and Explosive Use in the Action Alternatives to the 2013–2018 MMPA Permit Allotment

2.5.4.1 Training

As a comparison to the amount of training analyzed in the previous environmental planning compliance documents and as reflected in the 2013–2018 MMPA permit (Phase II), the Navy considered the type of sonar source that resulted in the greatest number of exposures to marine mammals, which was identified as hull-mounted mid-frequency active sonar. The differences between use of this system from Phase II to Phase III are best identified in three ways: (1) completion of unit-level training via synthetic means or through other training exercises, (2) reduction of sonar hours associated with a Composite Training Unit Exercise, and (3) reduction in the number of Composite Training Unit Exercises expected over a 5-year period.

During Phase II, all unit-level training using hull-mounted mid-frequency sonar was assumed to be conducted during discrete training events. However, current practice indicates that some unit-level training is completed through synthetic training, as well as concurrent with other training exercises (e.g., unit-level training can be completed simultaneously while conducting an integrated training exercise). Alternative 1 accounts for the use of synthetic training and concurrent unit-level training within other exercises, although this assumes risk in the event additional live training is necessary. To preserve the ability for the Navy to conduct all unit-level sonar training as discrete, at-sea exercises, Alternative 2 does not provide for the reduction in hours for unit-level training using hull-mounted mid-frequency sonar.

Composite Training Unit Exercises are major exercises that involve multiple platforms and numerous hours of sonar to meet mission objectives. During Phase II, each Composite Training Unit Exercise was assumed to require 1,000 hours of hull-mounted mid-frequency sonar. Through analysis of data collected during the Phase II permit period, the Navy determined that this assumption overestimated the amount of hull-mounted mid-frequency sonar that was typically used in a Composite Training Unit Exercise by 400 hours. As such, for both Alternatives 1 and 2, an estimated 600 hours of hull-mounted mid-frequency sonar is included for each Composite Training Unit Exercise.

Comparisons of proposed hull-mounted mid-frequency sonar hours to the hours permitted from 2013 to 2018 are depicted in Figure 2.5-1 and Figure 2.5-2.

The Fleet Response Plan, in place during Phase II, identified a requirement to conduct four Composite Training Unit Exercises per year in the Pacific Fleet. For Phase III, the number of Composite Training Unit Exercises to be conducted is reduced, with fewer proposed exercises in Alternative 1 and Alternative 2. Alternative 1 reduces from the 2013–2018 permitted level the number of Composite Training Unit Exercises to be conducted during any 5-year period in the Pacific Fleet by analyzing representative years (in addition to maximum planned years) of training activity to account for the variability of training cycles and deployment schedules. Alternative 1 analyzes two years of three Composite Training Unit Exercises (maximum years) and three years of two Composite Unit Training Exercises (representative years) occurring in the Pacific Fleet. Alternative 1 will analyze no more than 12 Composite Training Unit Exercises over any 5-year period into the foreseeable future. Alternative 2 analyzes a maximum number of Composite Training Unit Exercises planned per year (three), for a total of 15 over the 5-year period. A comparison of the number of Composite Training Unit Exercises from the 2013–2018 permitted levels to the Action Alternatives is provided in Figure 2.5-3.

After analyzing the level of explosive activities conducted during Phase II, the Navy identified that some explosive sources were incorrectly classed into bins with greater net explosive weights than actually is present in the munition (see Section 3.0.3.3.2.1, Explosions in Water, for a discussion of explosive classification bins). For example, 20 mm rounds were considered in bin E1 (defined as 0.1–0.25 pounds net explosive weight) during Phase II, but have less than 0.1 pound of net explosive weight (defined as bin E0) and are, therefore, analyzed qualitatively instead of quantitatively for Phase III. Additionally, in Phase II, munitions within the same category were all analyzed with the highest net explosive weight for all munitions in that category. For example, most bombs were analyzed as bin E12 (to account for the largest potential for environmental impact), whereas many fall within bins E9 and E10. For Phase III, munitions were divided into more appropriate bins based on current and anticipated weapon inventory.

Due to the re-binning of multiple munitions, comparing the use of a single bin or type of explosive in Phase III (similar to the comparison above for sonar) is not prudent. Figure 2.5-4 provides the change in explosive use per bin for all training activities between the 2013–2018 permitted level and the two action alternatives.

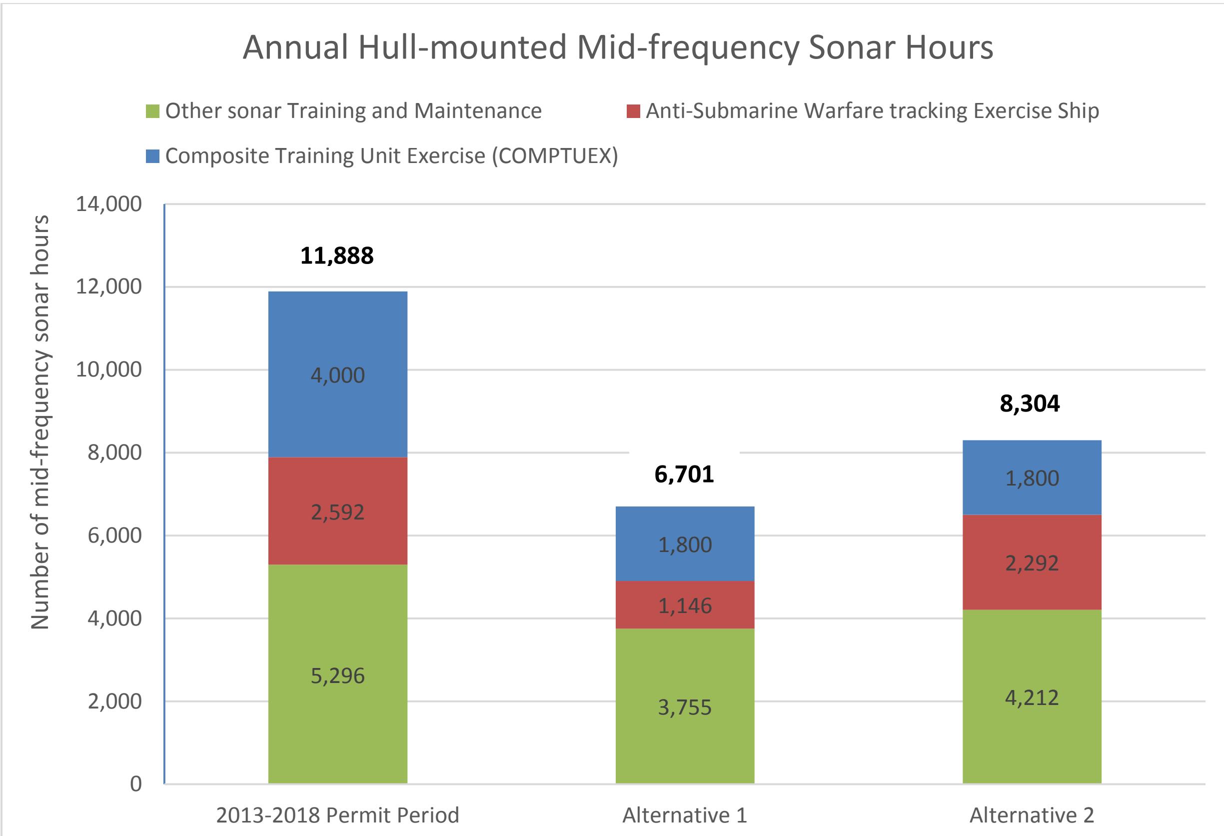

Figure 2.5-1: Proposed Maximum Year of Hull-Mounted Mid-Frequency Sonar Hour Use by Activity During Training Compared to the Number Authorized in the 2013–2018 Marine Mammal Protection Act Permit

Note: As represented here, Alternative 1 assumes three Composite Unit Training Exercises, conducted at a lower level of hull-mounted active sonar used and where 50 percent of requirements are met through synthetic training or other training exercises, and where all annual and non-annual training activities are carried out in any given year of the 5-year period.

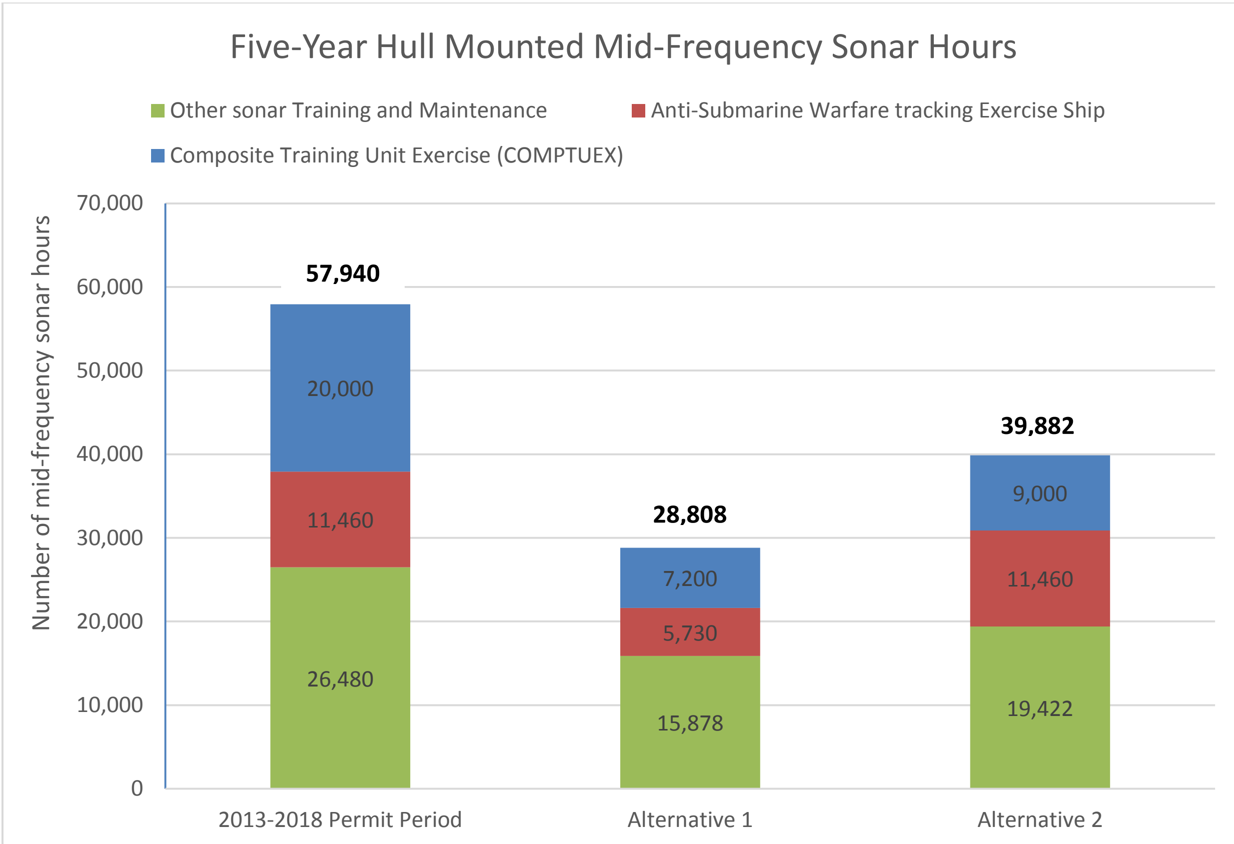

Figure 2.5-2: Proposed 5-Year Total Hull-Mounted Mid-Frequency Sonar Hour Use by Activity During Training Compared to the Number Authorized in the 2013–2018 Marine Mammal Protection Act Permit

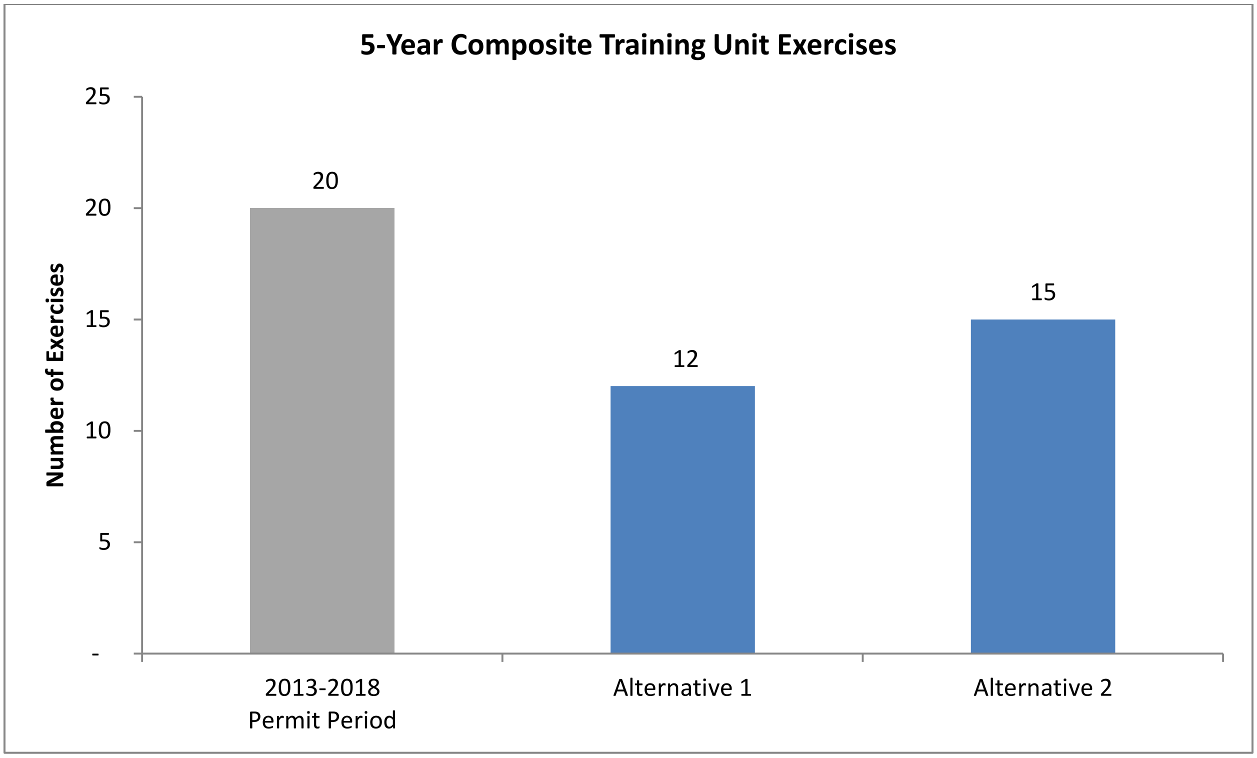

Figure 2.5-3: Proposed Number of Composite Training Unit Exercises over a 5-Year Period Compared to Number Authorized in the 2013–2018 Marine Mammal Protection Act Permit

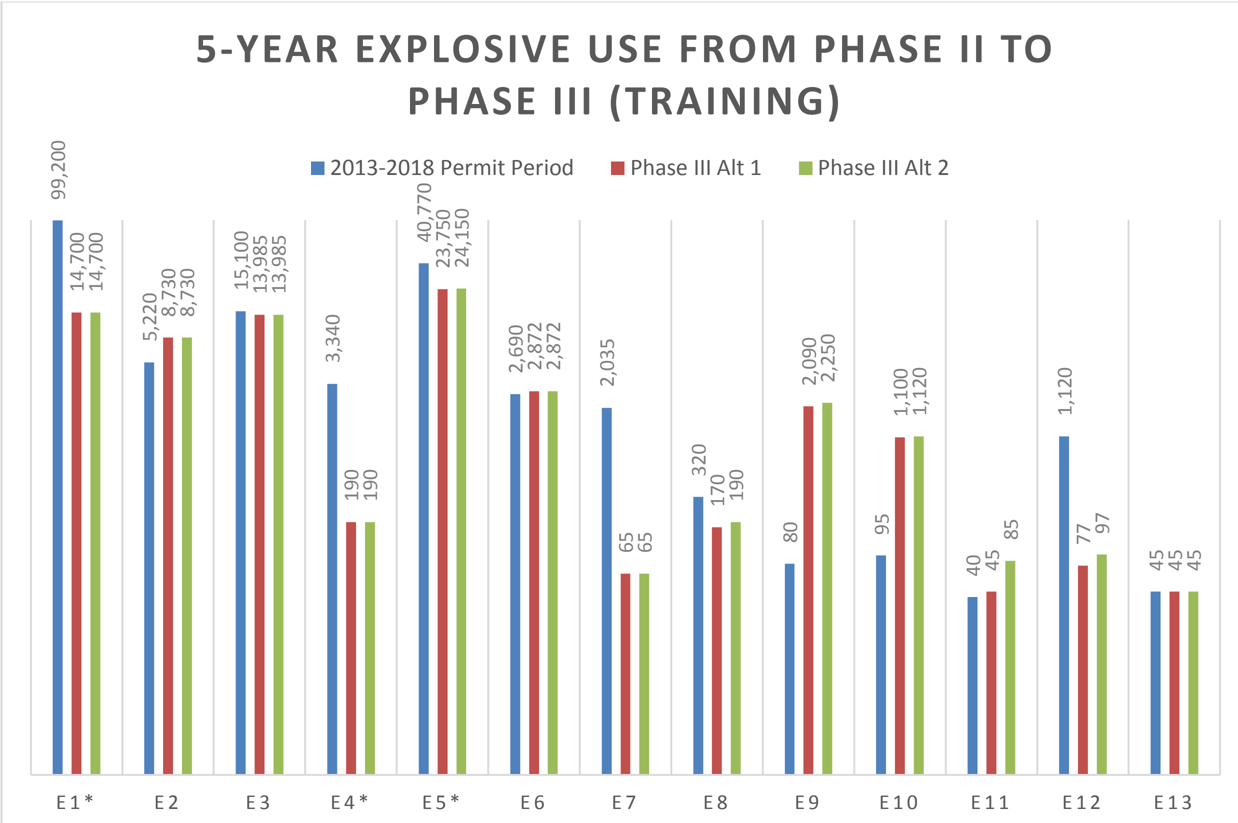

Figure 2.5-4: Proposed Explosives Use (for both Action Alternatives) During Training Activities Compared to the 2013–2018 Marine Mammal Protection Act Permit

Note: This chart is presented on a logarithmic scale to better represent a wide range of values.

2.5.4.2 Testing

As described in Sections 1.4.3.2 (Methods of Testing), 2.5.2.2 (Testing) and 2.5.3.2 (Testing), the Navy's testing community faces a number of challenges in accurately defining future testing requirements. These challenges include varying funding availability, changes in Congressional and DoD/Navy priorities in response to emerging threats in the world and the acquisition of new technologies that introduce increased uncertainties in the timeline, tempo, or success of a system's testing schedule. As it does now, the Navy testing community took into account these same challenges in projecting requirements for the 2013–2018 (Phase II) testing timeframe. Although the best information available to the Navy has always been taken into account, as a result of the implementation of Phase II, the Navy testing community has improved its ability to obtain and define that information and, consequently, its ability to project future testing needs. It is expected that over time, the Navy's ability to project future testing requirements will continue to improve with increasing refinement of the process and additional historical data. Nonetheless, the inherent challenges and uncertainties in testing, as described previously, will continue to make projection of future testing requirements challenging.

The majority of platforms, weapons and systems that were proposed for testing during the Phase II timeframe are the same or very similar to those proposed to be tested in the future. However, the Navy projects the need to test some platforms, weapons, and systems will increase, while others will decrease, as compared to the testing requirements that were proposed for the Phase II timeframe.

Overall, the Navy is projecting a net increase in the need to test systems that use sonar and a net decrease for explosives use, as proposed under Alternative 1, and as compared to the proposed testing requirements of the Phase II timeframe. These future projections are based on improvements in the Navy's understanding of requirements, the completion of test phases of certain projects since Phase II, the addition of test phases anticipated to start after December 2018, and the projected testing of new types of equipment since the 2013–2018 timeframe.

2.6 Proposed Training and Testing Activities for Both Alternatives

2.6.1 Proposed Training Activities

All proposed training activities are listed in Table 2.6-1.

Table 2.6-1: Proposed Training Activities

Activity Name	*Annual # of Activities*[1]		*5-Year # of Activities*		*Location*
	Alt 1	*Alt 2*	*Alt 1*	*Alt 2*	
Major Training Exercises – Large Integrated Anti-Submarine Warfare					
Composite Training Unit Exercise	2-3	3	12	15	SOCAL, PMSR[3]
Rim of the Pacific Exercise[2]	0–1	1	2	2	HRC
	0–1	1	2	2	SOCAL, PMSR[3]
Major Training Exercises – Medium Integrated Anti-Submarine Warfare					
Fleet Exercise/Sustainment Exercise	1	1	3	5	HRC
	5	7	22	35	SOCAL, PMSR[3]
Undersea Warfare Exercise	3	3	12	15	HRC
Integrated/Coordinated Training					
Small Integrated Anti-Submarine Warfare	1	1	2	5	HRC
	2-3	3	12	15	SOCAL
Medium Coordinated Anti-Submarine Warfare	2	2	10	10	HRC
	2	2	2	2	SOCAL
Small Coordinated Anti-Submarine Warfare	2	2	10	10	HRC
	10–14	14	58	70	SOCAL
Air Warfare					
Air Combat Maneuver	814		4,070		HRC
	6,000		30,000		SOCAL
Air Defense Exercise	185		925		HRC
	550		2,750		SOCAL
Gunnery Exercise Air-to-Air Medium Caliber	5		25		SOCAL
Gunnery Exercise Surface-to-Air Large Caliber	51		255		HRC
	165		825		SOCAL

Table 2.6-1: Proposed Training Activities (continued)

Activity Name	*Annual # of Activities*[1]		*5-Year # of Activities*		*Location*
	Alt 1	*Alt 2*	*Alt 1*	*Alt 2*	
Air Warfare (continued)					
Gunnery Exercise Surface-to-Air Medium Caliber	72		72		HRC
	195		195		SOCAL
	20		100		HSTT Transit Corridor
Missile Exercise Air-to-Air	62		310		HRC
	4		20		SOCAL
Missile Exercise Surface-to-Air	30		150		HRC
	36		180		SOCAL
Missile Exercise – Man Portable Air Defense System	4		20		SOCAL
Amphibious Warfare					
Amphibious Assault	12		60		HRC
	18		90		SOCAL
Amphibious Assault – Battalion Landing	2		10		SOCAL
Amphibious Marine Expeditionary Unit Exercise	2–3	3	12	15	SOCAL
Amphibious Marine Expeditionary Unit Integration Exercise	2–3	3	12	15	SOCAL
Amphibious Raid	2,426		12,130		SOCAL
Expeditionary Fires Exercise/Supporting Arms Coordination Exercise	8		40		SOCAL
Humanitarian Assistance Operations	2		10		HRC
	1		5		SOCAL
Marine Expeditionary Unit Composite Training Unit Exercise	2–3	3	12	15	SOCAL
Naval Surface Fire Support Exercise – At Sea	15		75		HRC
Naval Surface Fire Support Exercise – Land-Based Target	55		275		SOCAL
Anti-Submarine Warfare					
Anti-Submarine Warfare Torpedo Exercise – Helicopter	6		30		HRC
	104		520		SOCAL
Anti-Submarine Warfare Torpedo Exercise – Maritime Patrol Aircraft	10		50		HRC
	25		125		SOCAL
Anti-Submarine Warfare Torpedo Exercise – Ship	50		250		HRC
	117		585		SOCAL

Table 2.6-1: Proposed Training Activities (continued)

<table>
<tr><th rowspan="2">Activity Name</th><th colspan="2">Annual # of Activities[1]</th><th colspan="2">5-Year # of Activities</th><th rowspan="2">Location</th></tr>
<tr><th>Alt 1</th><th>Alt 2</th><th>Alt 1</th><th>Alt 2</th></tr>
<tr><td colspan="6">Anti-Submarine Warfare (continued)</td></tr>
<tr><td rowspan="2">Anti-Submarine Warfare Torpedo Exercise – Submarine</td><td colspan="2">48</td><td colspan="2">240</td><td>HRC</td></tr>
<tr><td colspan="2">13</td><td colspan="2">65</td><td>SOCAL</td></tr>
<tr><td rowspan="3">Anti-Submarine Warfare Tracking Exercise – Helicopter</td><td colspan="2">159</td><td colspan="2">795</td><td>HRC</td></tr>
<tr><td colspan="2">524</td><td colspan="2">2,620</td><td>SOCAL, PMSR[3]</td></tr>
<tr><td colspan="2">6</td><td colspan="2">30</td><td>HSTT Transit Corridor</td></tr>
<tr><td rowspan="2">Anti-Submarine Warfare Tracking Exercise – Maritime Patrol Aircraft</td><td colspan="2">32</td><td colspan="2">160</td><td>HRC</td></tr>
<tr><td colspan="2">56</td><td colspan="2">280</td><td>SOCAL, PMSR[3]</td></tr>
<tr><td rowspan="2">Anti-Submarine Warfare Tracking Exercise – Ship</td><td>224[4]</td><td>224</td><td>1,120[4]</td><td>1,120</td><td>HRC</td></tr>
<tr><td>423[4]</td><td>423</td><td>2,115[4]</td><td>2,115</td><td>SOCAL, PMSR[3]</td></tr>
<tr><td rowspan="3">Anti-Submarine Warfare Tracking Exercise – Submarine</td><td colspan="2">200</td><td colspan="2">1,000</td><td>HRC</td></tr>
<tr><td colspan="2">50</td><td colspan="2">250</td><td>SOCAL</td></tr>
<tr><td colspan="2">7</td><td colspan="2">35</td><td>HSTT Transit Corridor</td></tr>
<tr><td rowspan="2">Service Weapons Test</td><td colspan="2">2</td><td colspan="2">10</td><td>HRC</td></tr>
<tr><td colspan="2">1</td><td colspan="2">5</td><td>SOCAL</td></tr>
<tr><td colspan="6">Electronic Warfare</td></tr>
<tr><td rowspan="2">Counter Targeting Chaff Exercise – Aircraft</td><td colspan="2">19</td><td colspan="2">95</td><td>HRC</td></tr>
<tr><td colspan="2">140</td><td colspan="2">700</td><td>SOCAL</td></tr>
<tr><td rowspan="2">Counter Targeting Chaff Exercise – Ship</td><td colspan="2">37</td><td colspan="2">185</td><td>HRC</td></tr>
<tr><td colspan="2">125</td><td colspan="2">625</td><td>SOCAL</td></tr>
<tr><td rowspan="2">Counter Targeting Flare Exercise</td><td colspan="2">19</td><td colspan="2">95</td><td>HRC</td></tr>
<tr><td colspan="2">130</td><td colspan="2">650</td><td>SOCAL</td></tr>
<tr><td rowspan="2">Electronic Warfare Operations</td><td colspan="2">33</td><td colspan="2">165</td><td>HRC</td></tr>
<tr><td colspan="2">350</td><td colspan="2">1,750</td><td>SOCAL</td></tr>
<tr><td colspan="6">Expeditionary Warfare</td></tr>
<tr><td>Dive and Salvage Operations</td><td colspan="2">12</td><td colspan="2">60</td><td>HRC</td></tr>
<tr><td rowspan="2">Personnel Insertion/Extraction – Surface and Subsurface</td><td colspan="2">182</td><td colspan="2">910</td><td>HRC</td></tr>
<tr><td colspan="2">449</td><td colspan="2">2,245</td><td>SOCAL</td></tr>
<tr><td rowspan="2">Personnel Insertion/Extraction – Swimmer/Diver</td><td colspan="2">495</td><td colspan="2">2,475</td><td>HRC</td></tr>
<tr><td colspan="2">330</td><td colspan="2">1,650</td><td>SOCAL</td></tr>
<tr><td rowspan="2">Small Boat Attack</td><td colspan="2">6</td><td colspan="2">6</td><td>HRC</td></tr>
<tr><td colspan="2">115</td><td colspan="2">575</td><td>SOCAL</td></tr>
</table>

Table 2.6-1: Proposed Training Activities (continued)

Activity Name	Annual # of Activities[1]		5-Year # of Activities		Location
	Alt 1	Alt 2	Alt 1	Alt 2	
Mine Warfare					
Airborne Mine Countermeasure – Mine Detection	10		50		SOCAL
Civilian Port Defense – Homeland Security Anti-Terrorism/Force Protection Exercise	1	1	5	5	Pearl Harbor, HI
	1–3	3	12	15	San Diego, CA
Limpet Mine Neutralization System	4		20		HRC
	90		450		SOCAL
Marine Mammal System	10		50		HRC
	175		875		SOCAL
Mine Countermeasure Exercise – Ship Sonar	30		150		HRC
	92		460		SOCAL
Mine Countermeasure Exercise – Surface	266		1,330		SOCAL
Mine countermeasures Mine Neutralization Remotely Operated Vehicle Operations	6		30		HRC
	372		1,860		SOCAL
Mine Countermeasures – Towed Mine Neutralization	340		1,700		SOCAL
Mine Laying	6		30		HRC
	18		90		SOCAL
Mine Neutralization Explosive Ordnance Disposal	20		100		HRC
	170		850		SOCAL
Submarine Launched Mobile Mines	1		5		HRC
	1		5		SOCAL
Submarine Mine Exercise	40		200		HRC
	12		60		SOCAL
Surface Ship Object Detection	42		210		Pearl Harbor, Hawaii
	164		820		San Diego, California
Underwater Demolitions Multiple Charge – Mat Weave and Obstacle Loading	18		90		SOCAL
Underwater Demolition Qualification and Certification	25		125		HRC
	120		600		SOCAL

Table 2.6-1: Proposed Training Activities (continued)

Activity Name	*Annual # of Activities*[1]		*5-Year # of Activities*		*Location*
	Alt 1	*Alt 2*	*Alt 1*	*Alt 2*	
Surface Warfare					
Bombing Exercise Air-to-Surface	187		935		HRC
	640		3,200		SOCAL
	5		25		HSTT Transit Corridor
Gunnery Exercise Air-to-Surface Medium Caliber	217		1,085		HRC
	363		1,815		SOCAL
Gunnery Exercise Air-to-Surface Small Caliber	585		2,925		HRC
	2,040		10,200		SOCAL
Gunnery Exercise Surface-to-Surface Boat Medium Caliber	10		50		HRC
	14		70		SOCAL
Gunnery Exercise Surface-to-Surface Boat Small Caliber	25		125		HRC
	200		1,000		SOCAL
Gunnery Exercise Surface-to-Surface Ship Large Caliber	32		160		HRC
	200		1,000		SOCAL
	13		65		HSTT Transit Corridor
Gunnery Exercise Surface-to-Surface Ship Medium Caliber	50		250		HRC
	180		900		SOCAL
	40		200		HSTT Transit Corridor
Gunnery Exercise Surface-to-Surface Ship Small Caliber	65		325		HRC
	355		1,775		SOCAL
	20		100		HSTT Transit Corridor
Independent Deployer Certification Exercise/Tailored Surface Warfare Training	1		5		SOCAL
Integrated Live Fire	1		5		HRC
	1		5		SOCAL
Laser Targeting – Aircraft	50		250		HRC
	910		4,550		SOCAL
Maritime Security Operations	70		350		HRC
	250		1,250		SOCAL
Missile Exercise Air-to-Surface	10		50		HRC
	210		1,050		SOCAL

Table 2.6-1: Proposed Training Activities (continued)

Activity Name	*Annual # of Activities*[1]		*5-Year # of Activities*		*Location*
	Alt 1	*Alt 2*	*Alt 1*	*Alt 2*	
Surface Warfare (continued)					
Missile Exercise Air-to-Surface – Rocket	227		1,135		HRC
	246		1,230		SOCAL
Missile Exercise Surface-to-Surface	20		100		HRC
	10		50		SOCAL
Sinking Exercise	1–3	3	7	15	HRC
	0-1	1	1	5	SOCAL
Other Training Activities					
Elevated Causeway System	2		10		SOCAL
Kilo Dip	60		300		HRC
	2,400		12,000		SOCAL
Offshore Petroleum Discharge System	4		20		HRC
	6		30		SOCAL
Precision Anchoring	20		100		HRC
	75		375		SOCAL
Submarine Navigation Exercise	220		1,100		Pearl Harbor, Hawaii
	80		400		San Diego Bay, California
Submarine Sonar Maintenance and Systems Checks	260		1,300		HRC
	260		1,300		Pearl Harbor, HI
	93		465		SOCAL
	92		460		San Diego Bay, CA
	10		50		HSTT Transit Corridor
Submarine Under Ice Certification	12		60		HRC
	6		30		SOCAL
Surf Zone Test Detachment/Equipment Test and Evaluation	200		1,000		SOCAL
Surface Ship Sonar Maintenance and Systems Checks	75		375		HRC
	80		400		Pearl Harbor, HI
	250		1,250		SOCAL
	250		1,250		San Diego, CA
	8		40		HSTT Transit Corridor

Table 2.6-1: Proposed Training Activities (continued)

Activity Name	Annual # of Activities[1]		5-Year # of Activities		Location
	Alt 1	Alt 2	Alt 1	Alt 2	
Other Training Activities (continued)					
Unmanned Aerial System Training and Certification	20		100		HRC
	10		50		SOCAL
Unmanned Underwater Vehicle Training - Certification and Development	25		125		HRC
	10		50		SOCAL
Waterborne Training	500		2,500		HRC
	500		2,500		SOCAL

[1]For activities where the number of events varies between years, a range is provided to indicate the representative range in the number of events that may occur in a given year. The first number is the typical or nominal number that could occur in a given year and the second number is the maximum number not to be exceeded annually. This range does not preclude the Navy from conducting fewer than the nominal number indicated in a given year. For activities where no variation is anticipated, only the maximum number of events within a single year is provided.

[2]Rim of the Pacific (RIMPAC) training exercises typically occur every other year. This exercise is comprised of various activities accounted for elsewhere within Table 2.6-2. Some components of RIMPAC are conducted in SOCAL.

[3]PMSR indicates only the portion of the Point Mugu Sea Range that overlaps the Southern California portion of the HSTT Study Area, as described in Section 2.1.2.2 (Point Mugu Sea Range Overlap).

[4]For Anti-Submarine Warfare Tracking Exercise – Ship, Alternative 1, 50% of requirements are met through synthetic training or other training exercises

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California Range Complex, PMSR = Point Mugu Sea Range Overlap, HSTT = Hawaii-Southern California Training and Testing

2.6.2 TESTING

All proposed testing activities are listed in Table 2.6-2 through Table 2.6-5.

Table 2.6-2: Naval Air Systems Command Proposed Testing Activities

Activity Name	*Annual # of Activities[1]*		*5-Year # of Activities*		*Location*
	Alt 1	*Alt 2*	*Alt 1*	*Alt 2*	
Air Warfare					
Air Combat Maneuver Test	22		110		HRC
	110		550		SOCAL
Air Platform Weapons Integration Test	10		50		SOCAL
Air Platform-Vehicle Test	35		175		SOCAL
Intelligence, Surveillance, and Reconnaissance Test	14		70		HRC
	254		1,270		SOCAL
Anti-Submarine Warfare					
Anti-Submarine Warfare Torpedo Test	17–22	22	95	110	HRC
	35–71	71	247	355	SOCAL
Anti-Submarine Warfare Tracking Test – Helicopter	30–132	132	252	660	SOCAL
Anti-Submarine Warfare Tracking Test – Maritime Patrol Aircraft	54–61	65	284	325	HRC
	58–68	74	310	370	SOCAL
Sonobuoy Lot Acceptance Test	160		800		SOCAL
Electronic Warfare					
Chaff Test	5		25		HRC
	19		95		SOCAL
Electronic Systems Evaluation	4		20		SOCAL
Flare Test	5		25		HRC
	15		75		SOCAL
Mine Warfare					
Airborne Dipping Sonar Minehunting Test	0–12	12	12	60	SOCAL
Airborne Laser-Based Mine Detection System Test	20		100		SOCAL
Airborne Mine Neutralization System Test	11–31	37	75	185	SOCAL
Airborne Sonobuoy Minehunting Test	3–9	9	21	45	SOCAL
Mine Laying Test	1		5		HRC
	2		10		SOCAL

Table 2.6-2: Naval Air Systems Command Proposed Testing Activities (continued)

Activity Name	*Annual # of Activities*[1]		*5-Year # of Activities*		*Location*
	Alt 1	*Alt 2*	*Alt 1*	*Alt 2*	
Surface Warfare					
Air-to-Surface Bombing Test	8	8	40	40	HRC
	14	14	70	70	SOCAL
Air-to-Surface Gunnery Test	5		25		HRC
	30–60	60	240	300	SOCAL
Air-to-Surface Missile Test	18		90		HRC
	48–60	60	276	300	SOCAL
High Energy Laser Weapons Test	54		270		HRC
	54		270		SOCAL
Laser Targeting Test	5		25		SOCAL
Rocket Test	2		10		HRC
	18–22	22	102	110	SOCAL
Other Testing Activities					
Acoustic and Oceanographic Research	2		10		HRC
	3		15		SOCAL
Air Platform Shipboard Integration Test	7		35		HRC
	110		550		SOCAL
Kilo Dip	0–6	6	6	30	SOCAL
Shipboard Electronic Systems Evaluation	26		130		SOCAL
Undersea Range System Test	11–28	11–28	90		HRC

[1]For activities where the number of events varies between years, a range is provided to indicate the representative range in the number of events that may occur in a given year. The first number is the typical or nominal number that could occur in a given year and the second number is the maximum number not to be exceeded annually. This range does not preclude the Navy from conducting fewer than the nominal number indicated in a given year. For activities where no variation is anticipated, only the maximum number of events within a single year is provided.

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California Range Complex

Table 2.6-3: Naval Sea Systems Command Proposed Testing Activities

Activity Name	*Annual # of Activities*	*5-Year # of Activities*	*Location*
Anti-Submarine Warfare			
Anti-Submarine Warfare Mission Package Testing	22	110	HRC
	23	115	SOCAL
At-Sea Sonar Testing	16	78	HRC
	1	5	HRC SOCAL
	20–21	99	SOCAL
Countermeasure Testing	8	40	HRC
	4	20	HRC SOCAL
	11	55	SOCAL
	2	10	HSTT Transit Corridor
Pierside Sonar Testing	7	35	Pearl Harbor, Hawaii
	7	35	San Diego, California
Submarine Sonar Testing/Maintenance	4	20	HRC
	17	85	Pearl Harbor, Hawaii
	24	120	San Diego, California
Surface Ship Sonar Testing/Maintenance	3	15	HRC
	3	15	Pearl Harbor, Hawaii
	3	15	San Diego, California
	3	15	SOCAL
Torpedo (Explosive) Testing	8	40	HRC
	3	15	HRC SOCAL
	8	40	SOCAL
Torpedo (Non-Explosive) Testing	8	40	HRC
	9	45	HRC SOCAL
	8	40	SOCAL
Electronic Warfare			
Radar and Other System Testing	6	30	HRC SOCAL
	6	30	HRC
	1	5	Pearl Harbor, Hawaii
	1	5	San Diego, California
	40–46	206	SOCAL

Table 2.6-3: Naval Sea Systems Command Proposed Testing Activities (continued)

Activity Name	*Annual # of Activities*	*5-Year # of Activities*	*Location*
Mine Warfare			
Mine Countermeasure and Neutralization Testing	11	55	SOCAL
Mine Countermeasure Mission Package Testing	19	80	HRC
	58	290	SOCAL
Mine Detection and Classification Testing	2	10	HRC
	2	6	HRC SOCAL
	11	55	SOCAL
Surface Warfare			
Gun Testing – Large-Caliber	7	35	HRC
	72	360	HRC SOCAL
	7	35	SOCAL
Gun Testing – Medium-Caliber	4	20	HRC
	48	240	HRC SOCAL
	4	20	SOCAL
Gun Testing – Small-Caliber	1	5	HRC
	24	120	HRC SOCAL
	2	10	SOCAL
Kinetic Energy Weapon Testing	56	280	HRC SOCAL
Missile and Rocket Testing	13	65	HRC
	24	120	HRC SOCAL
	20	100	SOCAL
Unmanned Systems			
Unmanned Surface Vehicle System Testing	3	15	HRC
	4	20	SOCAL
Unmanned Underwater Vehicle Testing	3	15	HRC
	291	1,455	SOCAL
Vessel Evaluation			
Air Defense Testing	4	20	HRC
	9	45	SOCAL

Table 2.6-3: Naval Sea Systems Command Proposed Testing Activities (continued)

Activity Name	*Annual # of Activities*	*5-Year # of Activities*	*Location*
Vessel Evaluation (continued)			
In-Port Maintenance Testing	4	20	Pearl Harbor, Hawaii
	24	120	Pearl Harbor, Hawaii San Diego, California
	5	25	San Diego, California
Propulsion Testing	1	5	HRC
	13	65	HRC SOCAL
	10–11	51	SOCAL
Submarine Sea Trials – Propulsion Testing	1	5	HRC
	1	5	SOCAL
Submarine Sea Trials – Weapons System Testing	1	5	HRC
	1	5	SOCAL
Surface Warfare Testing	9	45	HRC
	63	313	HRC SOCAL
	14–16	72	SOCAL
Undersea Warfare Testing	7	35	HRC
	12–16	32	HRC SOCAL
	11	51	SOCAL
Vessel Signature Evaluation	4	20	HRC
	36	180	HRC SOCAL
	24	120	SOCAL
Other Testing Activities			
Insertion/Extraction	1	5	HRC
	1	5	SOCAL
Chemical and Biological Simulant Testing	220	1,100	HRC
	220	1,100	SOCAL
Non-Acoustic Component Testing	8	40	HRC
	16–17	81	SOCAL
Signature Analysis Operations	2	10	HRC
	1	5	SOCAL

Table 2.6-4: Office of Naval Research Proposed Testing Activities

Activity Name	Annual # of Activities		5-Year # of Activities		Location
	Alt 1	Alt 2	Alt 1	Alt 2	
Acoustic and Oceanographic Science and Technology					
Acoustic and Oceanographic Research	2		10		HRC
	4		20		SOCAL
Large Displacement Underwater Vehicle Testing	2		10		HRC
	2		10		SOCAL
	2		10		HSTT Transit Corridor
Long Range Acoustic Communications	3		15		HRC

Notes: HRC = Hawaii Range Complex, HSTT = Hawaii-Southern California Training and Testing, SOCAL = Southern California Range Complex

Table 2.6-5: Space and Naval Warfare Systems Command Proposed Testing Activities

Activity Name	Annual # of Activities[1]		5-Year # of Activities		Location
	Alt 1	Alt 2	Alt 1	Alt 2	
Other Testing Activities					
Anti-Terrorism/Force Protection	14		70		San Diego Bay, CA
	16		80		SOCAL
Communications	0–1	1	3	5	HRC
	10		50		SOCAL
Energy and Intelligence, Surveillance, and Reconnaissance/Information Operations Sensor Systems	11–15	15	61	75	HRC
	49–55	55	253	275	SOCAL
	8		40		HSTT Transit Corridor
Vehicle Testing	4		20		HRC
	166		830		SOCAL
	2		10		HSTT Transit Corridor

[1]For activities where the number of events varies between years, a range is provided to indicate the representative range in the number of events that may occur in a given year. The first number is the typical or nominal number that could occur in a given year and the second number is the maximum number not to be exceeded annually. This range does not preclude the Navy from conducting fewer than the nominal number indicated in a given year. For activities where no variation is anticipated, only the maximum number of events within a single year is provided.

Notes: HRC = Hawaii Range Complex, HSTT = Hawaii-Southern California Training and Testing, SOCAL = Southern California Range Complex

REFERENCES

U.S. Department of Defense. (2002). *Electromagnetic Environmental Effects: Requirements for Systems*. (MIL-STD-464A). Wright-Patterson Air Force Base, OH: U.S. Air Force/Aeronautical Systems Center.

U.S. Department of Defense. (2009). *Protecting Personnel from Electromagnetic Fields*. (DoD Instruction 6055.11). Washington, DC: Under Secretary of Defense for Acquisition, Technology, and Logistics.

U.S. Department of the Navy. (2008). *Hawaii Range Complex, Final Environmental Impact Statement/Overseas Environmental Impact Statement*. Pearl Harbor, HI: Hawaii Range Complex.

U.S. Department of the Navy. (2011). *U.S. Navy Dive Manual*. Washington, DC: Commander, Naval Sea Systems Command.

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Hawaii-Southern California Training and Testing

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3 AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

3.0 INTRODUCTION

This chapter describes existing environmental conditions in the Hawaii-Southern California Training and Testing (HSTT) Study Area as well as the analysis of resources potentially impacted by the Proposed Action described in Chapter 2 (Description of Proposed Action and Alternatives). The Study Area is described in Section 2.1 (Description of the Hawaii-Southern California Training and Testing Study Area) and depicted in Figure 2.1-1. The activities analyzed in this Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS) are largely a continuation of activities that have been ongoing for decades and were analyzed previously in the 2013 HSTT EIS/OEIS. Since the completion of the 2013 EIS/OEIS, new information is available and is used in this updated analysis. That information typically takes the form of new science or research that has been completed since 2013. This new information will be identified when it is used throughout the remainder of this updated EIS/OEIS.

This section provides the ecological characterization of the Study Area and describes the resources evaluated in the analysis. The Overall Approach to Analysis section explains that each proposed military readiness activity was examined to determine which environmental stressors could potentially impact a resource.

The sections following Section 3.0 (Introduction) provide analyses for each resource. The physical resources (air quality, and sediments and water quality) are presented first (Sections 3.1 and 3.2, respectively). Because impacts on air or water quality could affect all other marine resources, any potential impacts on air quality or sediments and water quality were considered as potential secondary stressors on the remaining resources to be described: vegetation, invertebrates, habitats, fishes, marine mammals, reptiles, and birds (Sections 3.3 through 3.9). Following the biological resource sections are human resource sections: cultural resources, socioeconomic resources, and public health and safety (Sections 3.10, 3.11, and 3.12).

Resources Analyzed:

Physical Resources:
- Air Quality
- Sediments and Water Quality

Biological Resources:
- Vegetation
- Invertebrates
- Habitats
- Fishes
- Marine Mammals
- Reptiles
- Birds

Human Resources:
- Cultural Resources
- Socioeconomic Resources
- Public Health and Safety

3.0.1 NAVY COMPILED AND GENERATED DATA

While preparing this document, the United States (U.S.) Department of the Navy (Navy) used the best available data, science, and information accepted by the relevant and appropriate regulatory and scientific communities to establish a baseline in the environmental analyses for all resources in accordance with the National Environmental Policy Act (NEPA), the Administrative Procedure Act (5 United States Code sections 551–596), and Executive Order 12114.

In support of the environmental baseline and environmental consequences sections for this and other environmental documents, the Navy has sponsored and supported both internal and independent research and monitoring efforts. The Navy's research and monitoring programs, as described below, are largely focused on filling data gaps and obtaining the most up-to-date science.

3.0.1.1 Marine Species Monitoring and Research Programs

The Navy has been conducting marine species monitoring for compliance with the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA) since 2006, both in association with training and testing events and independently. In addition to monitoring activities associated with regulatory compliance, two other Navy research programs provide extensive investments in basic and applied research: the Office of Naval Research Marine Mammals & Biology program, and the Living Marine Resources program. In fact, the U.S. Navy is one of the largest sources of funding for marine mammal research in the world. A survey of federally funded marine mammal research and conservation conducted by the Marine Mammal Commission found that the U.S. Department of Navy was the second largest source of funding for marine mammal activities (direct project expenditures, as well as associated indirect or support costs) in the United States in 2014, second only to National Oceanic and Atmospheric Administration Fisheries (Purdy, 2016).

The monitoring program has historically focused on collecting baseline data that supports analysis of marine mammal occurrence, distribution, abundance, and habitat use preferences in and around ocean areas in the Atlantic and Pacific where the Navy conducts training and testing. More recently, the priority has begun to shift towards assessing the potential response of individual species to training and testing activities. Data collected through the monitoring program serves to inform the analysis of impacts on marine mammals with respect to species distribution, habitat use, and potential responses to training and testing activities. Monitoring is performed using various methods, including visual surveys from surface vessels and aircraft, passive acoustics, and tagging. Additional information on the program is available on the U.S. Navy Marine Species Monitoring Program website, https://www.navymarinespeciesmonitoring.us/, which serves as a public online portal for information on the background, history, and progress of the program and also provides access to reports, documentation, data, and updates on current monitoring projects and initiatives.

The two other Navy programs previously mentioned invest in research on the potential effects of sound on marine species and develop scientific information and analytic tools that support preparation of environmental impact statements and associated regulatory processes under the MMPA and ESA, as well as support development of improved monitoring and detection technology and advance overall knowledge about marine species. These programs support coordinated science, technology, research, and development focused on understanding the effects of sound on marine mammals and other marine species, including physiological, behavioral, ecological, and population-level effects. Additional information on these programs and other ocean resources-oriented initiatives can be found at the U.S. Navy Green Fleet – Energy, Environment, and Climate Change website.

3.0.1.2 Navy's Quantitative Analysis to Determine Impacts to Sea Turtles and Marine Mammals

If proposed Navy activities introduce sound or explosive energy into the marine environment, an analysis of potential impacts on marine species is conducted. Data on the density of animals (number of animals per unit area) of each species and stock is needed, along with criteria and thresholds defining the levels of sound and energy that may cause certain types of impacts. The Navy's acoustic effects model takes the density and the criteria and thresholds as inputs and analyzes Navy training and testing activities. Finally, mitigation and animal avoidance behaviors are considered to determine the number of impacts that could occur. The inputs and process are described below. A detailed explanation of this analysis is provided in the technical report titled *Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase III Training and Testing* (U.S. Department of the Navy, 2018).

3.0.1.2.1 Marine Species Density Database

A quantitative analysis of impacts on a species requires data on their abundance and distribution in the potentially impacted area. The most appropriate metric for this type of analysis is density, which is the number of animals present per unit area. Estimating marine species density requires substantial surveys and effort to collect and analyze data to produce a usable estimate. The National Marine Fisheries Service (NMFS) is the primary agency responsible for estimating marine mammal and sea turtle density within the U.S. Exclusive Economic Zone. Other agencies and independent researchers often publish density data for species in specific areas of interest, including areas outside the U.S. Exclusive Economic Zone. In areas where surveys have not produced adequate data to allow robust density estimates, methods such as model extrapolation from surveyed areas, Relative Environmental Suitability models, or expert opinion are used to estimate occurrence. These density estimation methods rely on information such as animal sightings from adjacent locations, amount of survey effort, and the associated environmental variables (e.g., depth, sea surface temperature).

There is no single source of density data for every area of the world, species, and season because of the fiscal limitations, resources, effort involved in providing survey coverage to sufficiently estimate density, and practical limitations. Therefore, to characterize marine species density for large areas, such as the HSTT Study Area, the Navy compiled data from multiple sources and developed a protocol to select the best available density estimates based on species, area, and time (i.e., season). When multiple data sources were available, the Navy ranked density estimates based on a hierarchal approach to ensure that the most accurate estimates were selected. The highest tier included peer-reviewed published studies of density estimates from spatial models since these provide spatially-explicit density estimates with relatively low uncertainty. Other preferred sources included peer reviewed published studies of density estimates derived from systematic line-transect survey data, the method typically used for the NMFS marine mammal stock assessment reports. In the absence of survey data, information on species occurrence and known or inferred habitat associations have been used to predict densities using model-based approaches including Relative Environmental Suitability models. Because these estimates inherently include a high degree of uncertainty, they were considered the least preferred data source. In cases where a preferred data source was not available, density estimates were selected based on expert opinion from scientists.

The resulting Geographic Information System database includes seasonal density values for every marine mammal and sea turtle species present within the Study Area. This database is described in the technical report titled *U.S. Navy Marine Species Density Database Phase III for the Hawaii-Southern California Training and Testing Study Area* (U.S. Department of the Navy, 2017b), hereafter referred to as the Density Technical Report. These data were used as an input into the Navy Acoustic Effects Model.

The Density Technical Report describes the density models that were utilized in detail and provides detailed explanations of the models applied to each species density estimate. The below list describes models in order of preference.

1. Spatial density models are preferred and used when available because they provide an estimate with the least amount of uncertainty by deriving estimates for divided segments of the sampling

area. These models (see Becker et al., 2016; Forney et al., 2015) predict spatial variability of animal presence as a function of habitat variables (e.g., sea surface temperature, seafloor depth, etc.). This model is developed for areas, species, and, when available, specific timeframes (months or seasons) with sufficient survey data.

2. Stratified design-based density estimates use line-transect survey data with the sampling area divided (stratified) into sub-regions, and a density is predicted for each sub-region (see Barlow, 2016; Becker et al., 2016; Bradford et al., 2017; Campbell et al., 2015; Jefferson et al., 2014). While geographically stratified density estimates provide a better indication of a species' distribution within the Study Area, the uncertainty is typically high because each sub-region estimate is based on a smaller stratified segment of the overall survey effort.
3. Design-based density estimations use line-transect survey data from land and aerial surveys designed to cover a specific geographic area (see Carretta et al., 2015). These estimates use the same survey data as stratified design-based estimates, but are not segmented into sub-regions and instead provide one estimate for a large surveyed area.
4. Although relative environmental suitability models provide estimates for areas of the oceans that have not been surveyed using information on species occurrence and inferred habitat associations and have been used in past density databases, these models were not used in the current quantitative analysis.

When interpreting the results of the quantitative analysis, as described in the Density Technical Report, it is important to consider that "each model is limited to the variables and assumptions considered by the original data source provider. No mathematical model representation of any biological population is perfect, and with regards to marine mammal biodiversity, any single model will not completely explain the results" (U.S. Department of the Navy, 2017a). These factors and others described in the Density Technical Report should be considered when examining the estimated impact numbers in comparison to current population abundance information for any given species or stock.

3.0.1.2.2 Developing Acoustic and Explosive Criteria and Thresholds

Information about the numerical sound and energy levels that are likely to elicit certain types of physiological and behavioral reactions is needed to analyze potential impacts to marine species. Revised Phase III criteria and thresholds for quantitative modeling of impacts use the best available existing data from scientific journals, technical reports, and monitoring reports to develop thresholds and functions for estimating impacts on marine species. Working with NMFS, the Navy has developed updated criteria for marine mammals and sea turtles. Criteria for estimating impacts on marine fishes are also used in this analysis, which largely follow the *Sound Exposure Guidelines for Fishes and Sea Turtles* (Popper et al., 2014).

Since the release of the *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effect Analysis* in 2012 (U.S. Department of the Navy, 2012b), recent and emerging science has necessitated an update to these criteria and thresholds for assessing potential impacts on marine mammals and sea turtles. A detailed description of the Phase III acoustic and explosive criteria and threshold development is included in the supporting technical report *Criteria and Thresholds for U.S Navy Acoustic and Explosive Impact to Marine Mammals and Sea Turtles* (U.S. Department of the Navy, 2017c) and details are provided in each resource section. A series of behavioral studies, largely funded by the U.S. Navy, has led to a new understanding of how some species of marine mammals react to military sonar. This resulted in developing new behavioral response functions for estimating alterations in behavior. Additional information on auditory weighting functions has also emerged [e.g.,(Mulsow et al., 2015)] leading to developing a new methodology to predict auditory weighting functions for each hearing group along with the accompanying hearing loss thresholds. These criteria for predicting hearing loss in marine mammals were largely adopted by NMFS for species within their purview (National Marine Fisheries Service, 2018).

The Navy also uses criteria for estimating effects to fishes and the ranges to which those effects are likely to occur. A working group of experts generated a technical report that provides numerical criteria and relative likelihood of effects to fish within different hearing groups (i.e., fishes with no swim bladder versus fishes with a swim bladder involved in hearing) (Popper et al., 2014). Where applicable, thresholds and relative risk factors presented in the technical report were used to assist in the analysis of effects to fishes from Navy activities. Details on criteria used to estimate impacts on marine fishes are contained within the appropriate stressor section (e.g., sonar and other transducers, explosives) within Section 5.3 (Fishes). This panel of experts also estimated parametric criteria for the effects of sea turtle exposure to sources located at "near," "intermediate," and "far" distances, assigning "low," "medium," and "high" probability to specific categories of behavioral impacts (Popper et al., 2014).

3.0.1.2.3 The Navy's Acoustic Effects Model

The Navy's Acoustic Effects Model calculates sound energy propagation from sonar and other transducers, air guns, and explosives during naval activities and the energy or sound received by animat dosimeters. Animat dosimeters are virtual representations of marine mammals or sea turtles distributed in the area around the modeled naval activity that each animat records its individual sound "dose." The model bases the distribution of animats over the Study Area on the density values in the Navy Marine Species Density Database and distributes animats in the water column proportional to the known time that species spend at varying depths.

The model accounts for environmental variability of sound propagation in both distance and depth when computing the received sound level on the animats. The model conducts a statistical analysis based on multiple model runs to compute the estimated effects on animals. The number of animats that exceed the received threshold for an effect is tallied to provide an estimate of the number of marine mammals or sea turtles that could be affected.

Assumptions in the Navy model intentionally err on the side of overestimation when there are unknowns:

- Naval activities are modeled as though they would occur regardless of proximity to marine mammals or sea turtles (i.e., mitigation is not modeled) and without any avoidance of the activity by the animal. The final step of the quantitative analysis of acoustic effects is to consider the implementation of mitigation. For sonar and other transducers, the possibility that marine mammals or sea turtles would avoid continued or repeated sound exposures is also considered.
- Many explosions from munitions such as bombs and missiles actually occur upon impact with above-water targets and at the water's surface. However, for this analysis, sources such as these were modeled as exploding underwater. This overestimates the amount of explosive and acoustic energy entering the water.

The model estimates the impacts caused by individual training and testing activities. During any individual modeled event, impacts on individual animats are considered over 24-hour periods. The animats do not represent actual animals, but rather allow for a statistical analysis of the number of instances that marine mammals or sea turtles may be exposed to sound levels resulting in an effect. Therefore, the model estimates the number of instances in which an effect threshold was exceeded over the course of a year, but does not estimate the number of individual marine mammals or sea turtles that may be impacted over a year (i.e., some marine mammals or sea turtles could be impacted several times, while others would not experience any impact). A detailed explanation of the Navy's Acoustic Effects Model is provided in the technical report *Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase III Training and Testing* (U.S. Department of the Navy, 2018).

3.0.1.2.4 Accounting for Mitigation

3.0.1.2.4.1 Sonar and Other Transducers

The Navy implements mitigation measures (described in Section 5.3.2, Acoustic Stressors) during activities that use sonar and other transducers, including the power down or shut down (i.e., power off) of sonar when a marine mammal or sea turtle is observed in the mitigation zone. The mitigation zones encompass the estimated ranges to injury (including permanent threshold shift [PTS]) for a given sonar exposure. Therefore, the impact analysis quantifies the potential for mitigation to reduce the risk of PTS. Two factors are considered when quantifying the effectiveness of mitigation: (1) the extent to which the type of mitigation proposed for a sound-producing activity (e.g., active sonar) allows for observation of the mitigation zone prior to and during the activity; and (2) the sightability of each species that may be present in the mitigation zone, which is determined by species-specific characteristics and the viewing platform. A detailed explanation of the analysis is provided in the technical report *Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase III Training and Testing* (U.S. Department of the Navy, 2018).

In the quantitative analysis, consideration of mitigation measures means that, for activities where mitigation is feasible, some model-estimated PTS is considered mitigated to the level of temporary threshold shift (TTS). The quantitative analysis does not analyze the potential for mitigation to reduce TTS or behavioral effects, even though mitigation could also reduce the likelihood of these effects. In practice, mitigation also protects all unobserved (below the surface) animals in the vicinity, including other species, in addition to the observed animal. However, the analysis assumes that only animals sighted at the water surface would be protected by the applied mitigation. The analysis, therefore, does not capture the protection afforded to all marine species that may be near or within the mitigation zone.

The ability to observe the range to PTS was estimated for each training or testing event. The ability of Navy Lookouts to detect marine mammals or sea turtles in or approaching the mitigation zone is dependent on the animal's presence at the surface and the characteristics of the animal that influence its sightability (such as group size or surface active behavior). The behaviors and characteristics of some species may make them easier to detect. For example, based on small boat surveys between 2000 and 2012 in the Hawaiian Islands, pantropical spotted dolphins and striped dolphins were frequently observed leaping out of the water and Cuvier's beaked whales (Baird, 2013) and Blainville's beaked whales (HDR, 2012) were occasionally observed breaching. These behaviors are visible from a great distance and likely increase sighting distances and detections of these species. Environmental conditions under which the training or testing activity could take place are also considered such as the sea surface conditions, weather (e.g., fog or rain), and day versus night.

3.0.1.2.4.2 Explosions

The Navy implements mitigation measures (described in Section 5.3.3, Explosive Stressors) during explosive activities, including delaying detonations when a marine mammal or sea turtle is observed in the mitigation zone. The mitigation zones encompass the estimated ranges to mortality for a given explosive. Therefore, the impact analysis quantifies the potential for mitigation to reduce the risk of mortality due to exposure to explosives. Two factors are considered when quantifying the effectiveness of mitigation: (1) the extent to which the type of mitigation proposed for a sound-producing activity (e.g., gunnery exercise) allows for observation of the mitigation zone prior to and during the activity; and (2) the sightability of each species that may be present in the mitigation zone, which is determined by species-specific characteristics and the viewing platform. A detailed explanation of the analysis is provided in the technical report *Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase III Training and Testing* (U.S. Department of the Navy, 2018).

In the quantitative analysis, consideration of mitigation measures means that, for activities where mitigation is feasible, model-estimated mortality is considered mitigated to the level of injury. The impact analysis does not analyze the potential for mitigation to reduce non-auditory injury, PTS, TTS or behavioral effects, even though mitigation would also reduce the likelihood of these effects. In practice, mitigation also protects all unobserved (below the surface) animals in the vicinity, including other species, in addition to the observed animal. However, the analysis assumes that only animals sighted at the water surface would be protected by the applied mitigation. The analysis, therefore, does not capture the protection afforded to all marine species that may be near or within the mitigation zone.

3.0.1.2.5 Marine Mammal Avoidance of Sonar and other Transducers

Because a marine mammal is assumed to initiate avoidance behavior (e.g., tens of meters for most species groups) after an initial startle reaction when exposed to relatively high received levels of sound, a marine mammal could reduce its cumulative sound energy exposure over a sonar event with multiple pings (i.e., sound exposures). This would reduce risk of both PTS and TTS, although the quantitative analysis conservatively only considers the potential to reduce instances of PTS by accounting for marine mammals swimming away to avoid repeated high-level sound exposures. All reductions in PTS impacts from likely avoidance behaviors are instead considered TTS impacts.

3.0.1.3 Aquatic Habitats Database

The HSTT Aquatic Habitat Database was developed after the completion of the 2013 HSTT EIS/OEIS in order to refine the regional scale and overlapping habitat data used in the analysis of military expended materials and bottom-placed explosives. The database includes data sources ranging from regional-to-local scale. These data sources are subsequently combined to create a non-overlapping mosaic of habitat information that presents the highest quality data for a given location. The database primarily includes areas within the Study Area; however, there are also specific point locations for selected habitat types (e.g., artificial substrate). The current database is limited to abiotic (physical rather than biological) substrate types assessed in Section 3.5 (Habitats) for the current HSTT EIS/OEIS. A detailed description of the database is included as a supporting technical document with associated Geographic Information System and database deliverables (U.S. Department of the Navy, 2016b).

3.0.2 Ecological Characterization of the Study Area

The Study Area includes the intertidal and subtidal marine waters within the boundaries shown in Figure 2.1-1 but does not extend above the mean high tide line. Navy activities in the marine environment predominately occur within established operating areas (OPAREAs), range complexes, ports, and pierside locations. These locations are determined by Navy requirements, not to interfere with existing civilian and commercial maritime and airspace boundaries. The Navy-defined boundaries are not consistent with ecological boundaries, such as ecosystems, that may be more appropriate when assessing potential impacts on marine resources. Therefore, for the purposes of this document, the

Navy analyzed the marine resources in an ecological context to the extent possible to more comprehensively assess the potential impacts. The Navy used biogeographic classification systems to frame this ecological context.

Biogeographic classifications organize and describe the patterns and distributions of organisms and the biological and physical processes that influence this distribution. These biogeographic classification systems and areas are described in Section 3.0.2.1 (Biogeographic Classifications).

3.0.2.1 Biogeographic Classifications

For context, large marine ecosystems, where primary productivity is higher than open ocean areas (Bergmann et al., 2015) and their relation to the HSTT Study Area are presented below. Primary productivity is the rate of the formation of organic material from inorganic carbon via photosynthesis (e.g., by marine vegetation) or chemical reactions. Resources within open ocean areas are characterized by main oceanographic features (currents, gyres).

The large marine ecosystem classification system originated in the mid-1980s as a spatial planning tool to address transboundary management issues such as fisheries and pollution (Duda & Sherman, 2002). Large marine ecosystems are "relatively large areas of ocean space of approximately 200,000 square kilometers (km^2) or greater, adjacent to the continents in coastal waters where primary productivity is generally higher than in open ocean areas" (Bergmann et al., 2015). The large marine ecosystem concept for ecosystem-based management includes a five-module approach: (1) productivity, (2) fish and fisheries, (3) pollution and ecosystem health, (4) socioeconomics, and (5) governance. This approach is being applied to 16 international projects in Africa, Asia, Latin America, and Eastern Europe (Duda & Sherman, 2002) as well as to the large marine ecosystems in the HSTT Study Area described in the sections below (Aquarone & Adams, 2009a).

The large marine ecosystem classification system was advocated by the Council on Environmental Quality's Interagency Ocean Policy Task Force (The White House Council on Environmental Quality, 2010) as a marine spatial framework for coordinating regional planning in the waters off of the United States. The Study Area contains two large marine ecosystems, the Insular Pacific-Hawaiian and the California Current, and one open ocean area, the North Pacific Subtropical Gyre. The two large marine ecosystems are shown in Figures 3.0-1 and 3.0-2 and are briefly described in Section 3.0.2.1.1 (Insular Pacific-Hawaiian Large Marine Ecosystem) through Section 3.0.2.1.3 (North Pacific Subtropical Gyre Open Ocean Area).

3.0.2.1.1 Insular Pacific-Hawaiian Large Marine Ecosystem

The Insular Pacific-Hawaiian Large Marine Ecosystem encompasses an area of approximately 1,000,000 km^2. This large marine ecosystem extends 1,500 miles (mi.) from the Main Hawaiian Islands to the outer Northwestern Hawaiian Islands (Aquarone & Adams, 2009a) (Figure 3.0-1). This region is characterized by limited ocean nutrients, which leads to high biodiversity but low sustainable yields for fisheries (Aquarone & Adams, 2009a). Fisheries in this large marine ecosystem are comparatively smaller in scale than other U.S. fisheries. The average primary productivity within this large marine ecosystem is considered low at less than 150 grams (g) of carbon per square meter per year.

3.0.2.1.2 California Current Large Marine Ecosystem

The California Current Large Marine Ecosystem encompasses an area of approximately 2,200,000 km^2 (Aquarone & Adams, 2009b) (Figure 3.0-2). This large marine ecosystem is bordered by the United

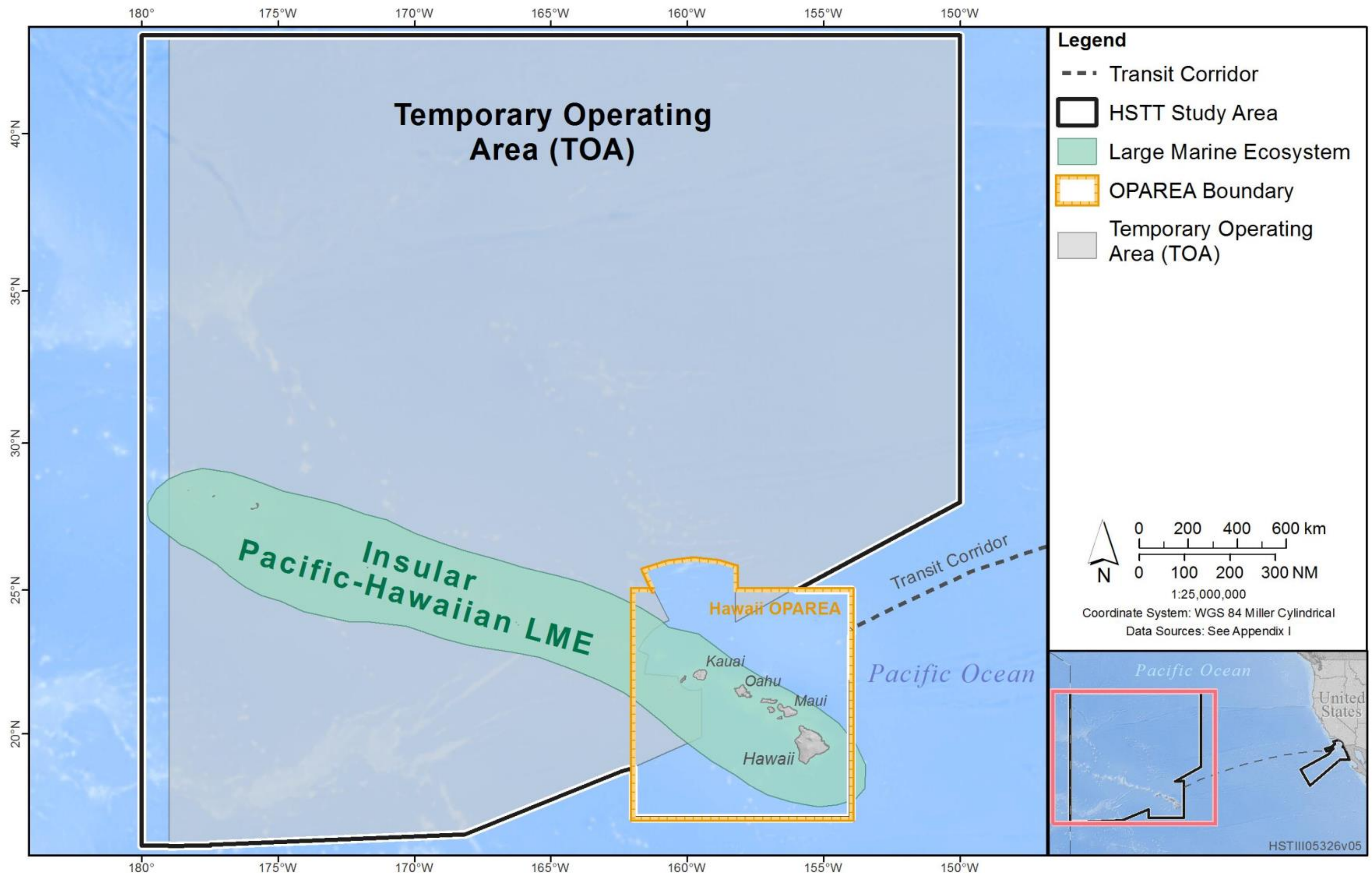

Figure 3.0-1: Large Marine Ecosystem of the Hawaii Range Complex

Notes: HSTT = Hawaii-Southern California Training and Testing, OPAREA = Operating Area

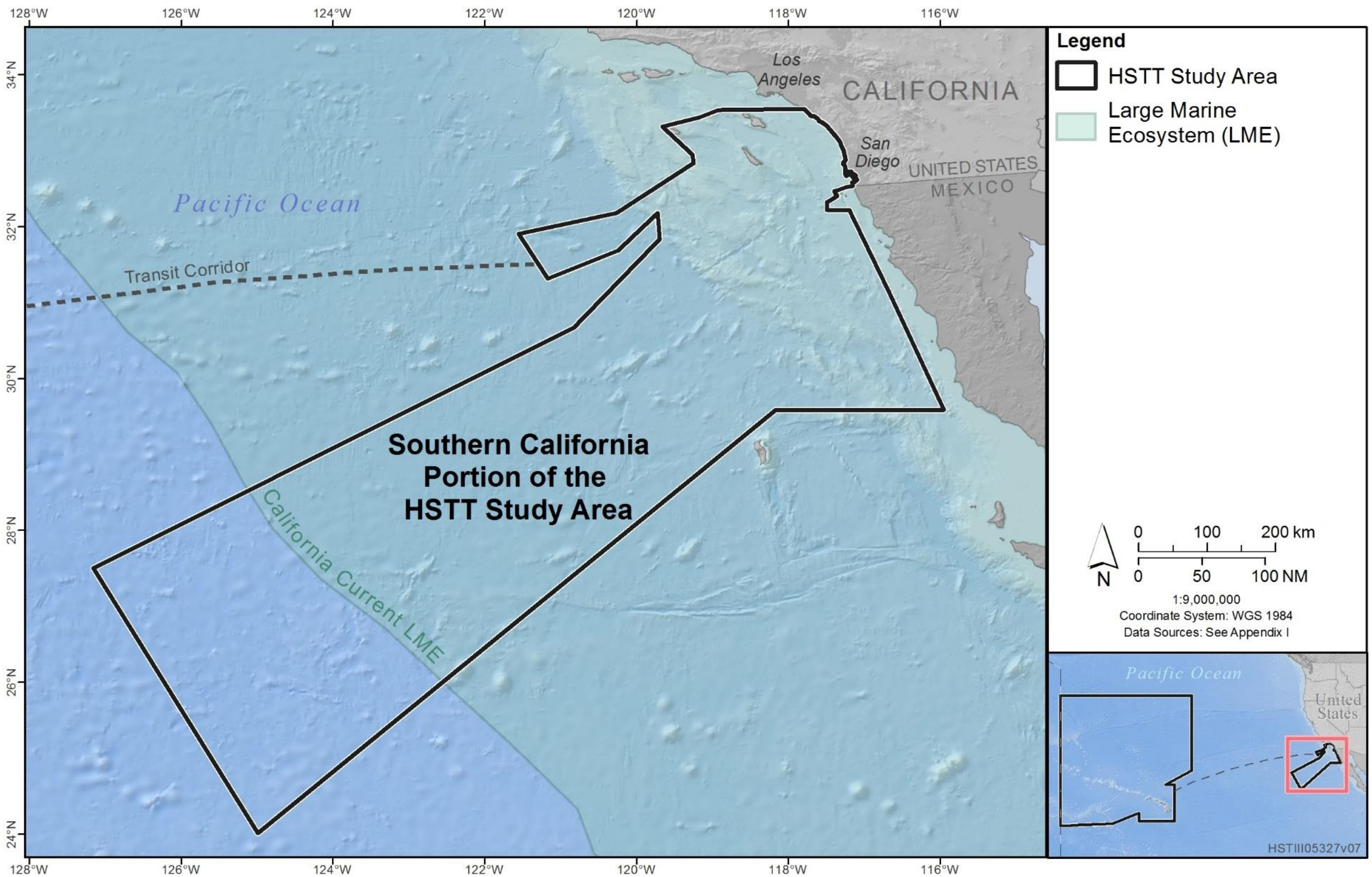

Figure 3.0-2: Large Marine Ecosystem of the Southern California Portion of the HSTT Study Area

Note: HSTT = Hawaii-Southern California Training and Testing

States and Mexico. Characteristics of this large marine ecosystem are the temperate climate and strong coastal upwelling (Aquarone & Adams, 2009b). The effects of variable coastal upwelling, the El Niño Southern Oscillation and the Pacific Decadal Oscillation, in this large marine ecosystem lead to yearly changes in the productivity of the ecosystem, including catch levels of harvest species (Aquarone & Adams, 2009b; California Current Integrated Ecosystem Assessment Team, 2015). The average primary productivity within this large marine ecosystem is low: less than 150 g of carbon per square meter per year (Aquarone & Adams, 2009b).

3.0.2.1.3 North Pacific Subtropical Gyre Open Ocean Area

North Pacific Ocean circulation is driven by the clockwise motion of the North Pacific Subtropical Gyre (Tomczak & Godfrey, 2003). The North Pacific Subtropical Gyre occurs between the equator and 50 degrees (°) North (N) and is defined to the north by the North Pacific Current, to the east by the California Current, to the south by the North Equatorial Current, and to the west by the Kuroshio Current (Tomczak & Godfrey, 2003). The entire HSTT Study Area lies completely within the North Pacific Subtropical Gyre. The North Pacific Subtropical Gyre, like all the ocean's large subtropical gyres, has extremely low rates of primary productivity (Valiela, 1995) caused by a persistent thermocline (a distinct layer of water in which temperature changes more rapidly with depth than it does above or below) that prevents the vertical mixing of water. Thermocline layers are present in the water column at varying depths throughout the world's oceans; however, in most areas, particularly nearshore, they are broken down seasonally, allowing nutrient-rich waters below the thermocline to replenish surface waters and fuel primary production.

3.0.2.2 Bathymetry

The discussion of bathymetry includes a general overview of the Study Area followed by more detailed sections focused on the Hawaii Range Complex and the Southern California portion of the Study Area. Bathymetry describes the surface features of the seafloor, and it is an important factor in understanding the potential impacts of Navy training and testing activities on the seafloor, the propagation of underwater sound, and species diversity.

The contour of the ocean floor as it descends from the shoreline has an important influence on the distribution of organisms, as well as the structure and function of marine ecosystems (Madden et al., 2009). The continental shelf and slope make up the continental margin of oceans. The typical zonation of oceans is shown in Figure 3.0-3.

The continental shelf extends seaward from shore with an average gradient of generally just 0.1°. The distance the shelf extends seaward varies from almost non-existent to over 650 kilometers (km) in certain areas, such as the Arctic shelf of Siberia (Pickard & Emery, 1990). The average width of the continental shelf off the western coast of the United States is approximately 65 km. At the termination of the shelf, referred to as the shelf break, it reaches a maximum depth of approximately 200 meters (m) (Tomczak & Godfrey, 2003; United Nations Educational Scientific and Cultural Organization, 2009).

The continental slope begins at the shelf break, which is defined by a dramatic increase in the seaward gradient of the seafloor to approximately 4 degrees (Pickard & Emery, 1990). The continental slope extends to an average depth of approximately 3,000 m and terminates at the continental rise. The continental rise extends from the base of the continental slope to a depth of approximately 4,000 m and terminates at the abyssal zone or deep sea bottom. Just as on land, there are flat plains, valleys, and mountains in the abyssal zone. Depths are approximately 6,000 m (Pickard & Emery, 1990). Abyssal zones in the Pacific Ocean reach depths greater than 8,000 m. The pelagic zone describes the water column extending from the intertidal zone seaward and from the water's surface to the seafloor. An important component of the pelagic zone to marine life in nearshore and oceanic waters is the photic zone. The photic zone is defined by the depth within the water column to which light penetrates. In the clearest oceanic water, light that is sufficient for photosynthesis will penetrate up to 200 m (Pickard & Emery, 1990).

Bathymetric features associated with the continental margin and the deep seafloor of the Study Area include submarine canyons, volcanic islands, atolls, seamounts, trenches, ridges, and plateaus.

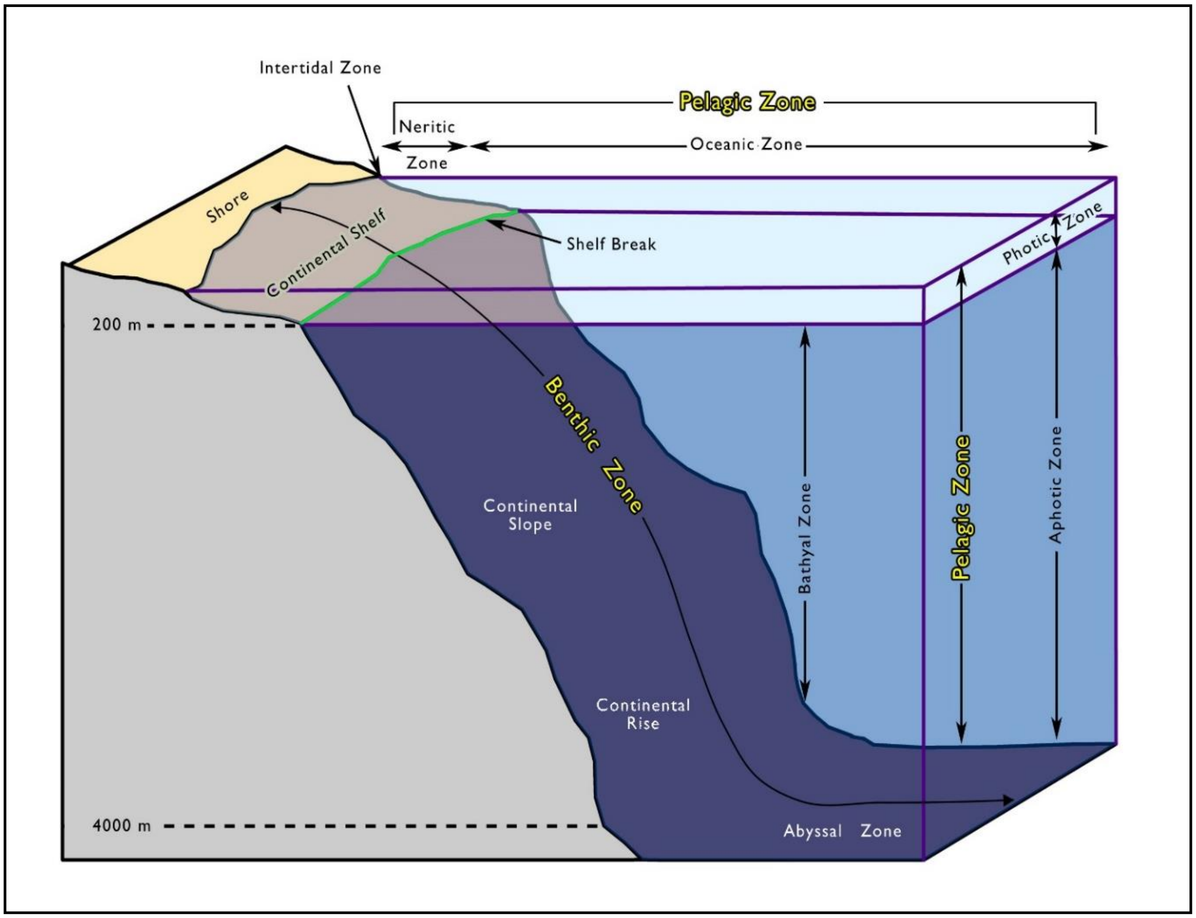

Figure 3.0-3: Three-Dimensional Representation of the Intertidal Zone (Shoreline), Continental Margin, Abyssal Zone, and Water Column Zones

3.0.2.2.1 Bathymetry of the Hawaii Range Complex

In the Hawaii Range Complex, bathymetric features are dominated by the Hawaiian Archipelago. Formed from volcanic eruptions, the Hawaiian Archipelago does not have a continental shelf (Figure 3.0-4). The Hawaiian Archipelago is composed of high islands, reefs, banks, atolls (coral reef islands surrounding a shallow lagoon), and seamounts (deep seafloor underwater mountains) (Polovina et al., 1995; Rooney et al., 2008). Other major bathymetric features in this region include submarine canyons, which reach depths greater than 2,000 m and have been identified off of Nihoa Island and Maro Reef, off of Oahu and Molokai islands, and off of Hawaii and Kauai islands (Vetter et al., 2010). Further from the archipelago, bathymetric features of the open ocean areas of the Hawaii Range Complex include seamounts and submarine canyons.

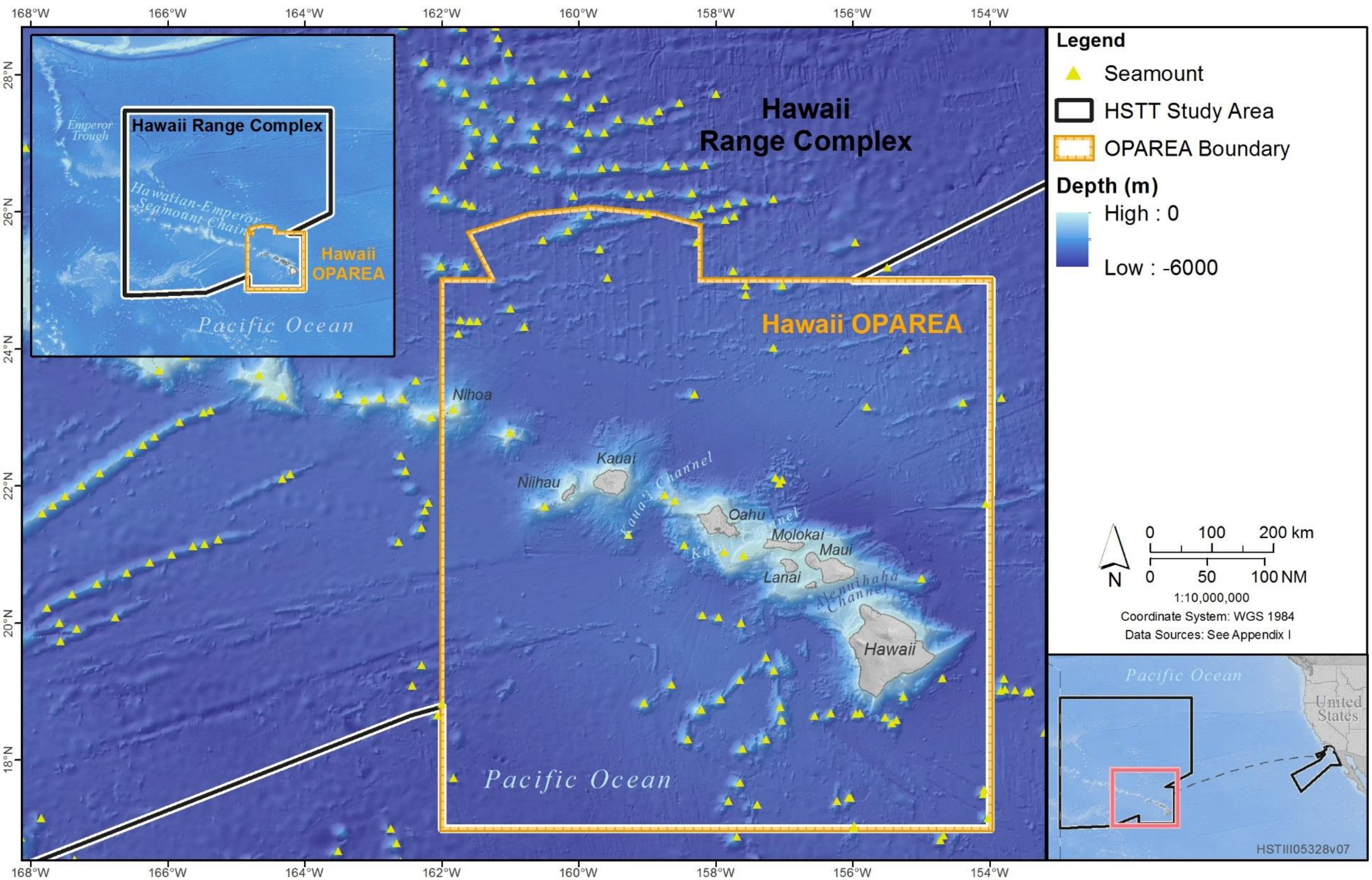

Figure 3.0-4: Bathymetry of the Main Hawaiian Islands

Notes: HSTT = Hawaii-Southern California Training and Testing, OPAREA = Operating Area

3.0.2.2.2 Bathymetry of the Southern California Portion of the HSTT Study Area

Bathymetric features of the California Current Large Marine Ecosystem and the Southern California portion of the Study Area include a continental shelf, a continental slope, a rise, and a deep seafloor (Figure 3.0-5).

The continental shelf off of Southern California is associated with a borderland, a broad irregular region that extends seaward off the continental shelf (Gorsline, 1992; Tomczak & Godfrey, 2003; United Nations Educational Scientific and Cultural Organization, 2009). The continental shelf extends from the shore to depths of approximately 200 m (Tomczak & Godfrey, 2003; United Nations Educational Scientific and Cultural Organization, 2009). The continental slope, beginning at the shelf break, descends steeply to seafloor. The continental slope is divided into the upper slope (200–800 m), which is adjacent to the shelf break; the mid-slope (800–1,400 m); and the lower slope (1,400–4,000 m). Beyond the lower slope is a relatively flat or gently sloping abyssal plain, typically at depths between 3,500 m and 6,500 m. Bathymetric features associated with the shelf and slope include elevated banks, seamounts, and steep ridges (Gorsline, 1992).

The shape of California's coastline south of Point Conception creates a broad ocean embayment known as the Southern California Bight (National Research Council, 1990). The Southern California Bight encompasses the area from Point Conception south into Mexico, including the Channel Islands. The Channel Islands archipelago is composed of eight volcanic islands that are located along the coastline of Southern California (Moody, 2000). The southernmost islands that occur in the Study Area include San Nicolas, Santa Catalina, and San Clemente islands, which are located off of California between Ventura and Los Angeles County (Moody, 2000). Bottom topography in the Southern California Bight varies from broad expanses of continental shelf to deep basins (National Research Council, 1990). Southwest of the Channel Islands lies the Patton Escarpment, a steep ridge with contours bearing in a northwesterly direction (Uchupi & Emery, 1963). This ridge drops approximately 1,500 m to the deep ocean floor. Between the Patton Escarpment and the mainland lie the Santa Rosa Cortes Ridge deep shelf basins (e.g., Catalina, San Clemente, East Cortes, West Cortes, San Nicolas, and Tanner); two important channels (Santa Barbara and San Pedro); and a series of escarpments, canyons, banks, and seamounts (e.g., Cortes Bank, Tanner Bank, 60 Mile Bank, Farnsworth Bank, and Lausen Sea Mount) (National Research Council, 1990). Farther to the southwest, beyond Patton Escarpment, the only major bottom feature is the Westfall Seamount. To the south, along the coast of Baja California, lie several additional banks and basins.

Submarine canyons dissect the continental shelf, slope, and rise off of Southern California and in the Study Area. These underwater canyons transport sediments from the continental shelf and slope to the deep seafloor, producing distinct sediment fans at their base (Covault et al., 2007). Major submarine canyons in the Study Area include the Coronado, La Jolla, Scripps, and Catalina.

3.0.2.3 Currents, Circulation Patterns, and Water Masses

To analyze the impact of Navy training and testing activities on marine resources (e.g., vegetation and animals) it is important to know where the resources occur in the Study Area. Some of the major factors that influence the distribution of marine resources are currents, circulation patterns, and water masses.

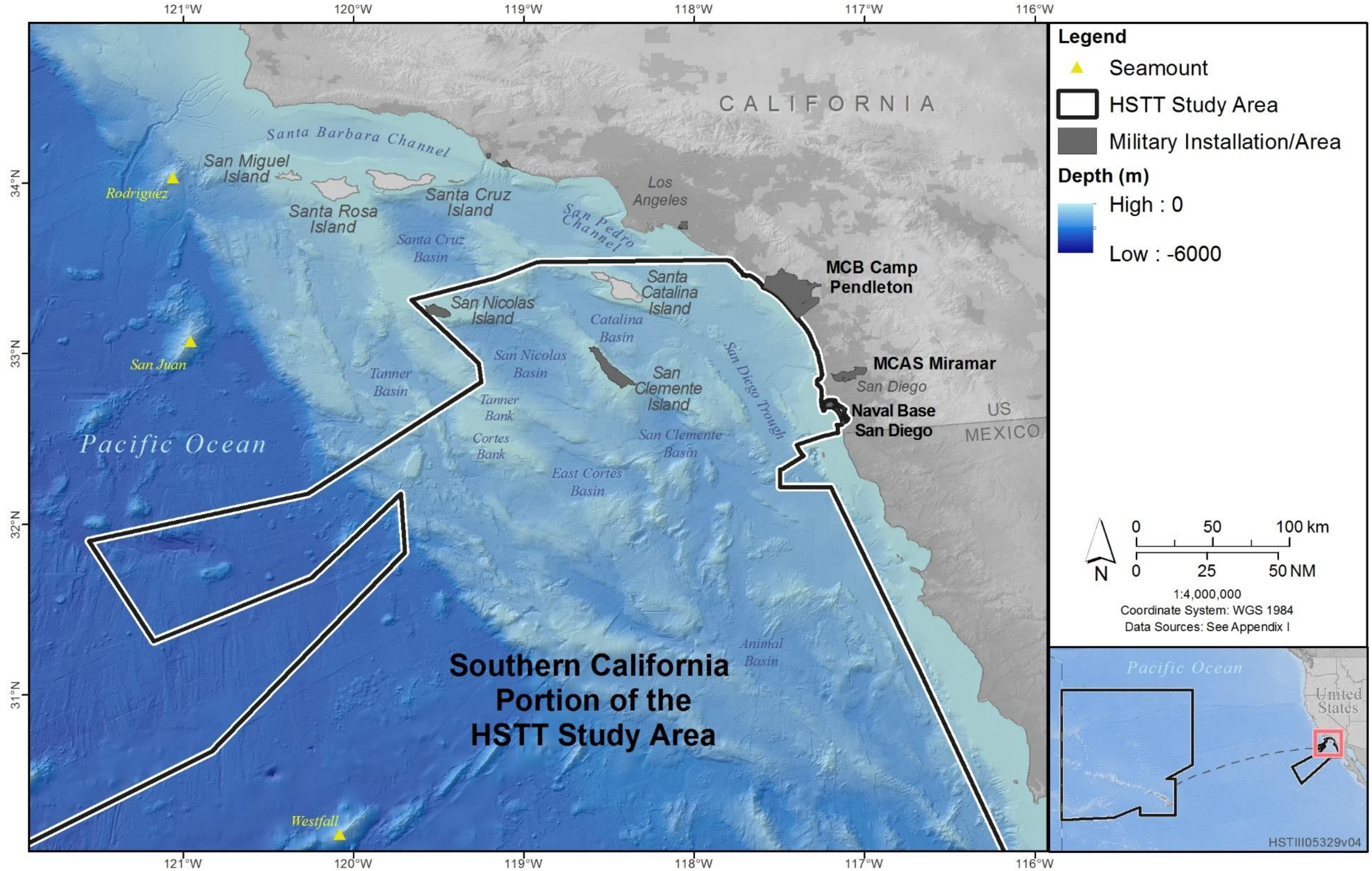

Figure 3.0-5: Bathymetry of the Eastern Part of the Southern California Portion of the Study Area

Notes: HSTT = Hawaii-Southern California Training and Testing, MCB = Marine Corps Base, MCAS = Marine Corps Air Station

Surface currents are horizontal movements of water primarily driven by the drag of the wind over the sea surface. Wind-driven circulation dominates in the upper 100 m of the water column and therefore drives circulation over continental shelves (Hunter et al., 2007). Surface currents of the Pacific Ocean include equatorial currents, circumpolar currents, eastern boundary, and western boundary currents. Major surface currents within the Study Area include the North Equatorial Current, North Hawaiian Ridge Current, and Hawaii Lee Current in the Hawaii OPAREA; and the California Current, California Countercurrent, and the Southern California Eddy in the Southern California portion of the HSTT Study Area (Figure 3.0-6 and Figure 3.0-7).

Current speeds in the world's oceans vary widely. Currents flowing along the western boundaries of oceans are narrow, deep, and swift and have speeds exceeding 1 m per second (Pickard & Emery, 1990). The western boundary current in the North Pacific is the Kuroshio Current, which flows northward off the coast of Japan at an average speed of 1.0–1.5 m per second. Eastern boundary currents, such as the California Current, are relatively shallow, broad, and slow-moving and travel toward the equator along the eastern boundaries of ocean basins. In general, eastern boundary currents carry cold waters from higher latitudes to lower latitudes, and western boundary currents carry warm waters from lower latitudes to higher latitudes (Reverdin et al., 2003).

Water masses throughout the world's oceans are defined by their chemical and physical properties. The temperature and salinity of a water mass determines its density. Density differences cause water masses to move both vertically and horizontally in relation to one another. Cold, salty, dense water formed at the surface will sink, whereas warm, less salty, and less dense water will rise. These density differences are responsible for large-scale, global ocean water circulation, which plays a major role in global climate variation and the transport of water, heat, nutrients, and larvae (Kawabe & Fujito, 2010).

Thermohaline circulation—also called the ocean conveyor belt or meridional overturning—is the continuous circulation of water masses throughout the ocean. This cycle begins with the sinking of dense waters and the subsequent formation of deep water masses in the North Atlantic and Southern oceans (Dickson & Brown, 1994). Deep water masses in the Study Area include Lower and Upper Circumpolar Deep Waters, Antarctic Circumpolar Current, and North Pacific Deep Water. Lower and Upper Circumpolar Deep Waters and Antarctic Intermediate Water are transported from the Antarctic Circumpolar Current to the North Pacific (Kawabe & Fujito, 2010). The eastern branch of the Lower Circumpolar Deep Water flows eastward south of the Hawaiian Ridge. The western portion of the Lower Circumpolar Deep Water upwells and is transformed into North Pacific Deep Water. North Pacific Deep Water mixes with Upper Circumpolar Deep Waters around the Hawaiian Islands.

Intermediate water masses (residing above deep water and below surface water) in the Study Area include Pacific Intermediate Water, Pacific Central Water, and Antarctic Intermediate Water (Johnson, 2008; Kawabe & Fujito, 2010). Pacific Intermediate Water is formed in the northwest portion of the North Pacific Subtropical Gyre and is transported into the California Current Large Marine Ecosystem (Talley, 1993).

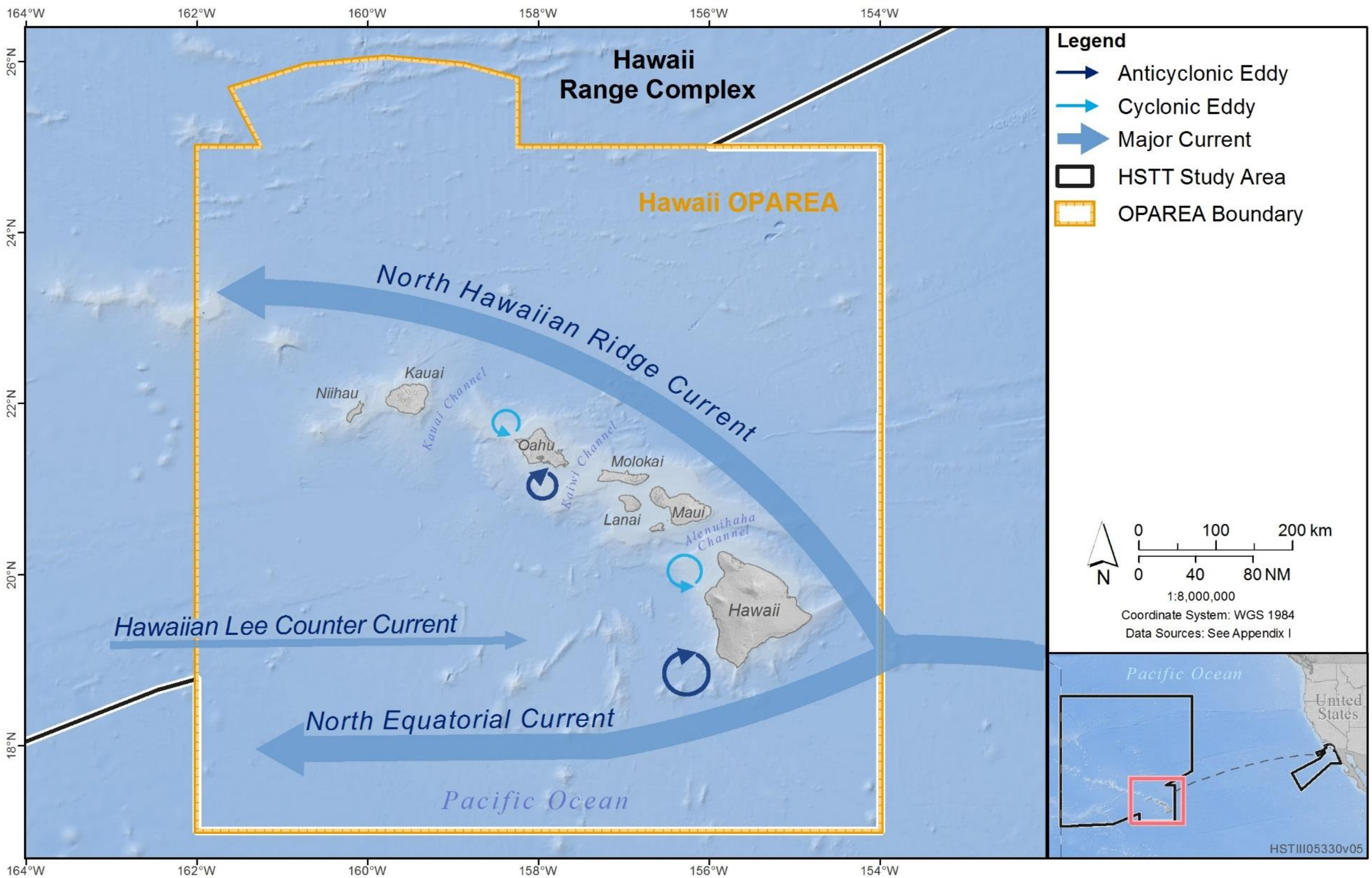

Figure 3.0-6: Surface Circulation in the Hawaiian Islands

Notes: HSTT = Hawaii-Southern California Training and Testing, OPAREA = Operating Area

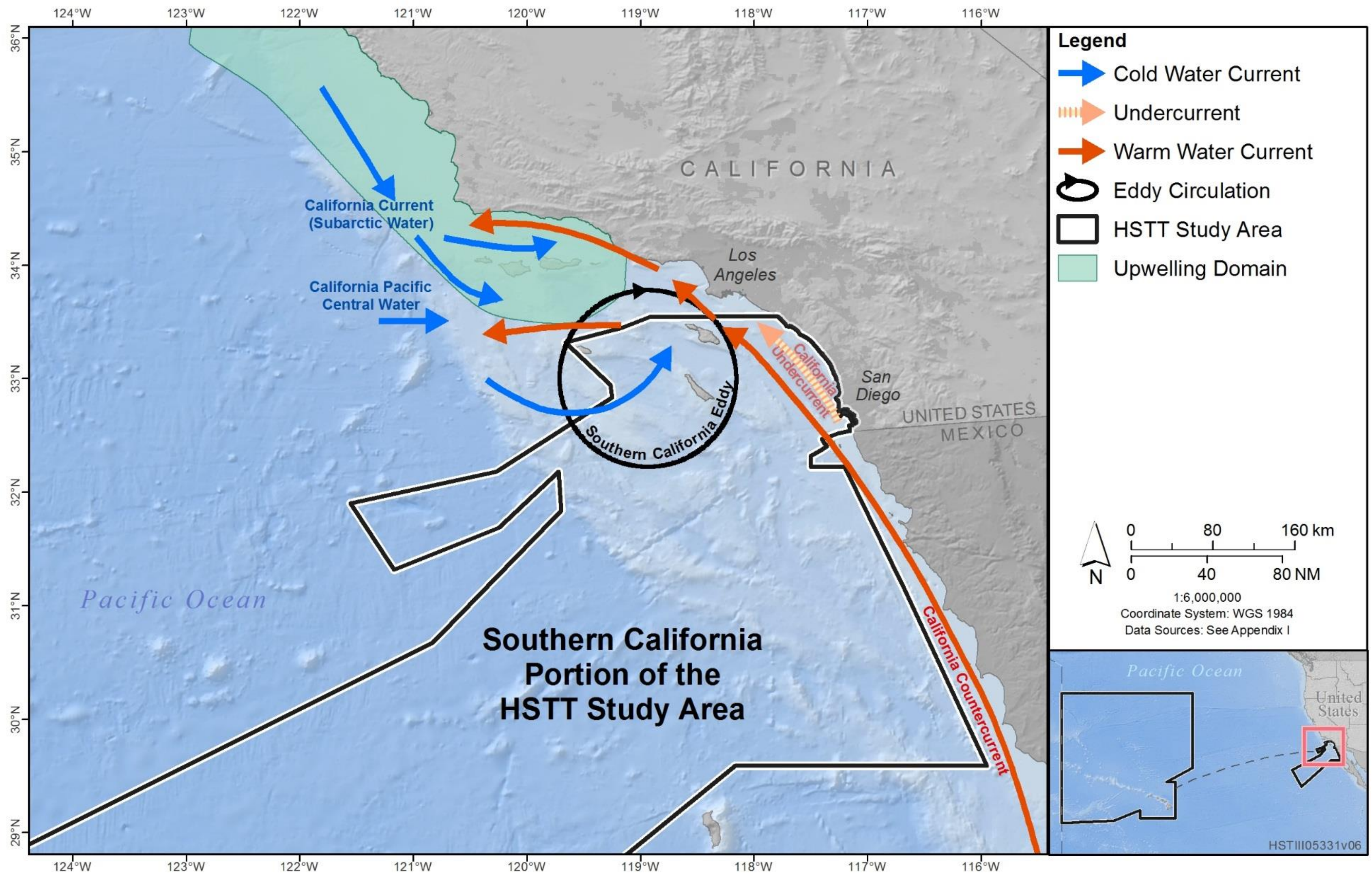

Figure 3.0-7: Surface Circulation in the Southern California Portion of the HSTT Study Area

Note: HSTT = Hawaii-Southern California Training and Testing

3.0.2.3.1 North Pacific Transition Zone

The North Pacific Transition Zone (Figure 3.0-8) is a convergence of the North Pacific Current, which forms the southern part of the North Pacific Subpolar Gyre (cold water), and the northern part of the North Pacific Subtropical Gyre (warm water). This convergence creates the Transition Zone Chlorophyll Front where cool, surface water with high concentrations of chlorophyll from the Alaska Gyre meets warm, low chlorophyll surface water from the North Pacific Subtropical Gyre (Polovina et al., 2001). Extending over 8,000 km across the North Pacific, the Transition Zone Chlorophyll Front shifts seasonally north and south about 1,000 km. In the winter the front is located at about 30–35° N latitude. In the summer, the front is located at about 40–45° N. Satellite telemetry data on movements of loggerhead turtles and detailed fisheries data for albacore tuna show that both travel along this front as they migrate across the North Pacific (Howell et al., 2010; North Pacific Marine Science Organization, 2004).

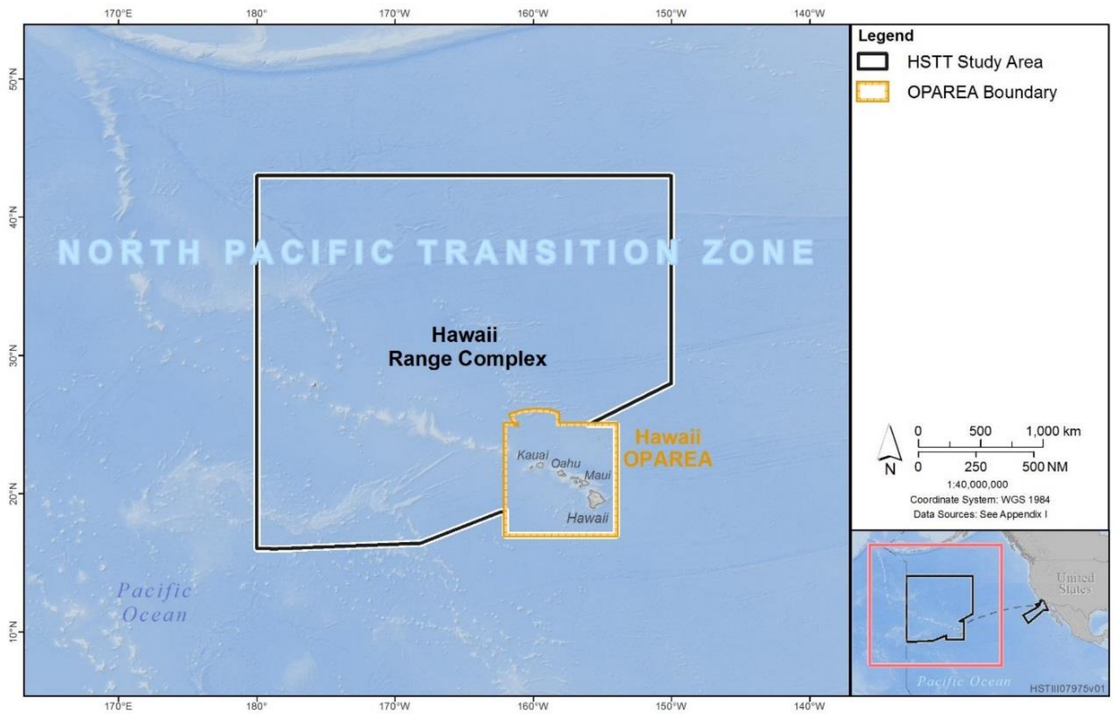

Figure 3.0-8: The North Pacific Transition Zone

3.0.2.3.2 Currents, Circulation Patterns, and Water Masses of the Hawaii Range Complex

The Hawaii portion of the Study Area is influenced by the North Pacific Current, North Equatorial Current, North Hawaiian Ridge Current, and Hawaii Lee Current. The North Pacific Current is an eastward flowing current that forms the upper boundary of the North Pacific Subtropical Gyre (Tomczak & Godfrey, 2003). The North Pacific Current in the eastern North Pacific splits at approximately 45–50° N and forms the northward flowing Alaska Current and the southward flowing California Current. The North Equatorial Current is a westward flowing current that splits at the Hawaiian Islands; one branch travels north along the Hawaiian Ridge to form the North Hawaiian Ridge Current (Itano & Holland, 2000). The North Hawaiian Ridge Current turns and continues westward at the tip of the Hawaiian Ridge (Qiu et al., 1997). The Hawaiian Lee Current occurs on the west side of the Hawaiian Islands and travels east toward the Islands (Chavanne et al., 2002). As the Hawaiian Lee Current approaches the Hawaiian

Islands, it appears to form a counterclockwise gyre centered at 20.5° N and a clockwise gyre centered at 19° N (Chavanne et al., 2002; Flament et al., 2009). The latter, clockwise gyre merges with the North Equatorial Current in the south (Chavanne et al., 2002; Flament et al., 2009). The North Equatorial Current is primarily driven by the northeast and southeast trade winds and therefore flows westward (Figure 3.0-6). This current is strongest during winter, particularly in February when the trade winds are also the strongest. The North Equatorial Current flows between 8° N and 15° N with an average velocity less than 0.3 m per second (Tomczak & Godfrey, 2003; Wolanski et al., 2003). The North Equatorial Current splits at the Hawaiian Islands; one branch travels north and the other continues west. The westward flowing branch of the North Equatorial Current approaches Japan and splits again, forming the southward flowing Mindanao Current and the northward flowing Kuroshio Current.

3.0.2.3.3 Currents, Circulation Patterns, and Water Masses of the Southern California Range Complex

The Southern California portion of the Study Area is dominated by the California Current System. The California Current System includes four major currents: the California Current, the California Undercurrent, the Southern California Countercurrent, and the Southern California Eddy (Batteen et al., 2003). The California Current flows south along the coasts of Washington, Oregon, California, and the Baja Peninsula, where it joins the North Pacific Subtropical Gyre via the westward flowing North Equatorial Current (Bograd, 2004). The California Current flows south, about 1,000 km offshore, along the entire coast of California (Batteen et al., 2003), and carries cold, low-salinity water with high dissolved oxygen and high nutrient concentrations southward (Gelpi & Norris, 2008; Tomczak & Godfrey, 2003). The California Current flows parallel to the continental borderland along Southern California at an average current speed of 0.15 m per second (Hickey, 1992).

Winds off the California Coast that blow towards the equator are redirected offshore (to the west) by the earth's rotation. The westerly winds force surface waters along the coast farther offshore, creating a lower sea surface height, which results in a pressure gradient that directs current flow toward the equator (Tomczak & Godfrey, 2003). Furthermore, as coastal waters are pushed offshore, upwelling results as the water at the surface is replaced from below by colder, subsurface water. Upwelling of deep water brings nutrients to the surface, enhancing primary production along the coast of California. However, the intensity of regional upwelling is affected by seasonal variability in wind direction and strength. Winds are strongest from May to June in waters off Southern California (Reid et al., 1958). During winter, the winds from the north weaken, surface waters are not pushed as far offshore, upwelling is reduced, and the circulation in the region is dominated by the Southern California Eddy and the Southern California Countercurrent (Batteen et al., 2003; Gelpi & Norris, 2008; Reid et al., 1958). The Southern California Countercurrent flows northward, inshore of the California Current, carrying warm, saline water with low dissolved oxygen and low nutrient concentrations into the Study Area (Hickey, 1992). During fall and winter, a portion of the Southern California Countercurrent continues north, past Point Conception, forming the Davidson Current (Batteen et al., 2003); however, the majority of the Southern California Countercurrent is entrained in the Southern California Eddy.

The Southern California Eddy is a semi-permanent counterclockwise gyre (Di Lorenzo, 2003; Dorman, 1982) formed as the trade winds act on the California Current and the California Countercurrent. Maximum strength of the eddy occurs in summer and fall when winds from the north are weak and the strength of the California Countercurrent is therefore greatest (Di Lorenzo, 2003). Persistent upwelling of nutrient-rich waters also occurs at the center of the gyre and results in enhanced primary production (Bograd et al., 2000). The California Current System is among the most productive areas in the world.

The California Undercurrent is a deep water current that flows northward along the entire coast of California. The strength of the Californian Undercurrent varies throughout the year, with peaks during summer and early fall. The current is typically at its weakest in spring and early summer (flow at depth may occasionally reverse and move south). The Californian Undercurrent flows inshore of the California Current (Gay & Chereskin, 2009), and at times may surface and combine with the California Counter Current to form the Davidson Current north of Point Conception. The California Undercurrent is composed of Pacific Equatorial Water and is therefore characterized by warm, salty, and nutrient poor water (Gay & Chereskin, 2009). The warm, salty waters of the California Undercurrent flow at about 100 m beneath the cold, nutrient rich waters of the California Current (Lynn et al., 2003; National Research Council, 1990).

The Subarctic Pacific water mass that occurs off Southern California includes the North Pacific Intermediate Water that is characterized as cold, low-salinity, nutrient-rich water (Blanton & Pattullo, 1970; North Pacific Marine Science Organization, 2004; Talley, 1993). Subarctic waters bring nutrients including nitrate, phosphate, and silica to Southern California (Bograd, 2004). Nitrogen and phosphorus are required by phytoplankton (small floating plants) for photosynthesis (Loh & Bauer, 2000). Photosynthesis is the production of chemical compounds into energy from sunlight. Therefore, these intrusions result in increases in phytoplankton densities, enhancing the rate at which organic matter is produced from the sun's energy (primary production) (Bograd, 2004).

3.0.2.4 Ocean Fronts

Ocean fronts are characterized by increased productivity and biomass (e.g., marine vegetation and animals) (Bost et al., 2009). Fronts are the boundaries between two water masses with distinct temperatures or densities and are characterized by rapid changes in specific water properties over short distances.

The Hawaii portion of the Study Area is influenced by the Subarctic Front and Subtropical Front (Norcross et al., 2003; North Pacific Marine Science Organization, 2004). The Subarctic Frontal Zone is at the northern boundary of the North Pacific Current and is located between 40° N and 43° N (North Pacific Marine Science Organization, 2004). The Subarctic Front develops between the cold, low-salinity, productive subarctic waters in the north and the low-nutrient subtropical waters of the central Pacific (Howell et al., 2010; North Pacific Marine Science Organization, 2004). The Subtropical Frontal Zone occurs between the cold, low-salinity surface waters of the north and the warm, higher-salinity subtropical waters from the south (North Pacific Marine Science Organization, 2004).

The Southern California portion of the Study Area is influenced by the Ensenada Front formed by the convergence of equatorial waters and waters of the California Current (Figure 3.0-7) (Venrick, 2000). The Ensenada Front is a broad zone where sharp gradients in temperature, salinities, and nutrient concentrations occur as these waters meet. The Ensenada Front appears between Point Conception and Punta Vizcaino, Mexico, and is present in the Study Area throughout most of the year. This front marks the boundary between the low-nutrient waters to the south and the high-nutrient, highly productive waters to the north (Santamaria-del-Angel et al., 2002). Therefore, this front is associated with a distinct species boundary between southern warm water species and northern cold water species (Chereskin & Niiler, 1994).

3.0.2.5 Water Column Characteristics and Processes

Seawater is made up of a number of components, including gases, salts, nutrients, dissolved compounds, particulate matter (solid compounds such as sand, marine organisms, and feces), and trace metals (Garrison, 1998). Seawater characteristics are primarily determined by temperature and the gases and solids dissolved in it.

Sea surface temperature varies considerably across the Pacific Ocean (see Figure 3.0-9), from season to season and from day to night. Sea surface temperatures are affected by atmospheric conditions, and can show seasonal variation in association with upwelling, climatic conditions, and latitude (Tomczak & Godfrey, 2003). Annual average sea surface temperatures increase from north to south in the North Pacific Subtropical Gyre (Flament et al., 2009) (Figure 3.0-9).

In the Hawaii open ocean portion of the Study Area, sea surface temperature ranges from 8° Celsius (C) in the North Pacific Current to 30°C in the North Pacific Subtropical Gyre (United Nations Educational Scientific and Cultural Organization, 2009). In the inland and open ocean Southern California portions of the Study Area, sea surface temperature ranges from approximately 12°C in winter to 21°C in summer (Bograd et al., 2000). The coldest sea surface temperatures typically occur in February, while the warmest temperatures typically occur in September.

Sea surface temperature and nutrients are also influenced by long-term climatic conditions, including El Niño, La Niña, the Pacific Decadal Oscillation, and climate change. The recurring El Niño pattern is one of the strongest in the ocean atmosphere system (Gergis & Fowler, 2009). El Niño events result in significantly warmer water in the tropical Pacific. Upwelling of cold, nutrient-rich water along the coasts of North and South America is drastically reduced. Previous El Niño events have coincided with large-scale redistribution of some West Coast marine mammals, fish, and sea turtles. Rockfish surveys in the beginning of the 2015 El Niño event indicated the likely influence of warm water, turning up large catches of species typically seen during strong El Niño periods, and some never before seen in the survey. They included record high catches of pelagic red crabs and California spiny lobster, and the survey's first-ever catches of warm-water species including greater Argonaut (a swimming octopus with a shell), slender snipefish, and subtropical krill (Milstein, 2015). Large-scale coral bleaching has also coincided with large El Niño events (Wilkinson & Hodgson, 1999). Figure 3.0-9 reflects sea surface temperatures during a typical non-El Niño year.

La Niña is the companion phase of El Niño. La Niña events are characterized by stronger than average easterly trade winds that push the warm surface waters of the tropical Pacific to the west and enhance upwelling along the eastern Pacific coastline (Bograd et al., 2000). The Pacific Decadal Oscillation is a long-term climatic pattern with alternating warm and cool phases (Mantua & Hare, 2002; Polovina et al., 1994).

Every 20–30 years, the surface waters of the central and northern Pacific Ocean (20° N and poleward) shift several degrees from their average temperature. This oscillation affects primary production in the eastern Pacific Ocean and, consequently, affects organism abundance and distribution throughout the food chain.

3.0.2.6 Abiotic Substrate

In the marine and estuarine environments of the HSTT Study Area there are a variety of types of surfaces, or substrates, on which organisms live. Nonliving (abiotic) substrates can be categorized based on the grain size of unconsolidated material: “Soft” (e.g., sand, mud), “Intermediate” (e.g., cobble, gravel), and “Hard” (e.g., bedrock, boulders, artificial structures).

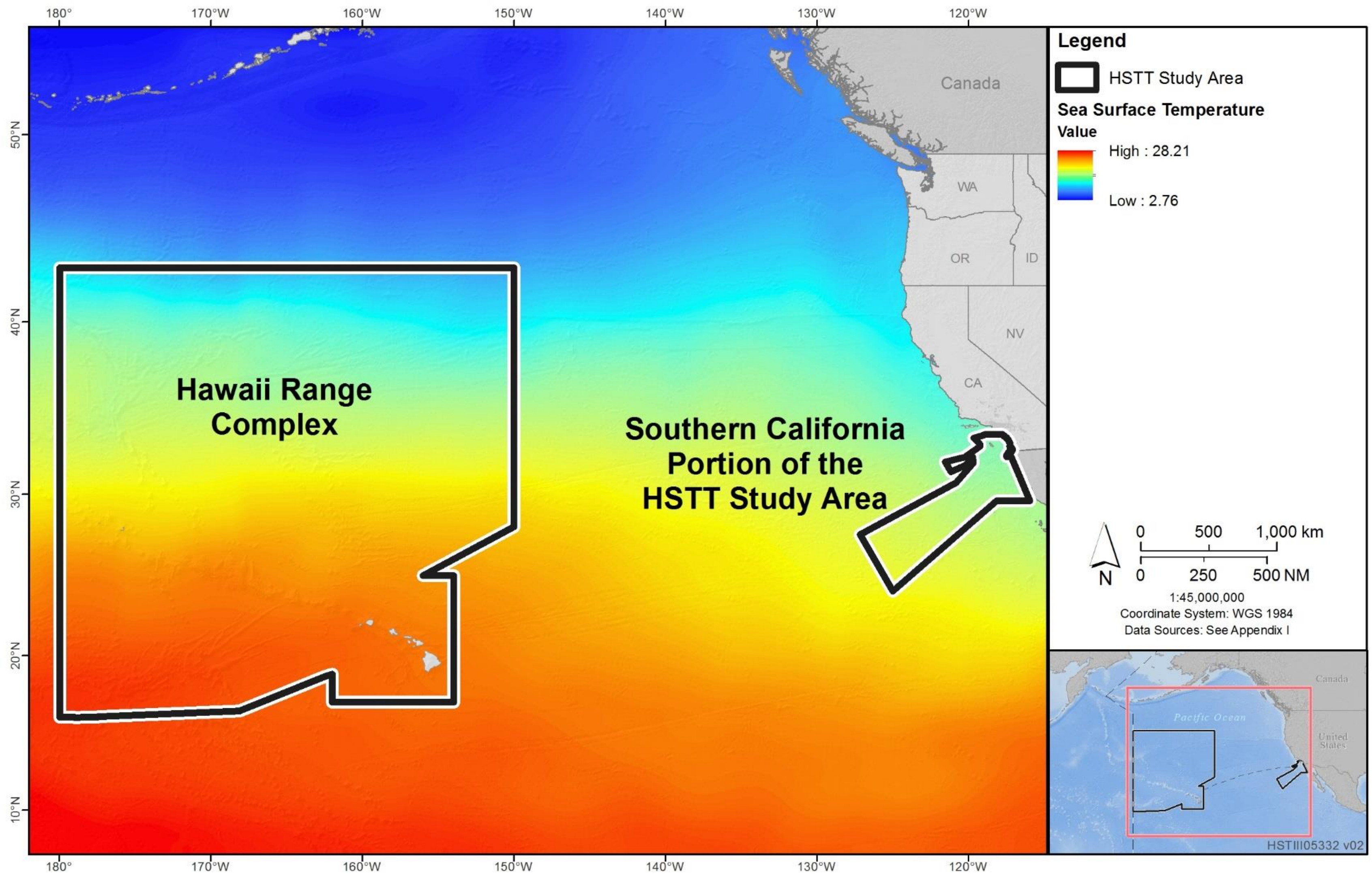

Figure 3.0-9: Average Sea Surface Temperature in the Study Area (2011–2015)

Note: HSTT = Hawaii-Southern California Training and Testing

3.0.3 Overall Approach to Analysis

The Navy's overall approach to analysis in this EIS/OEIS is consistent with the approach used in previous analyses and included the following general steps:

- identifying resources and stressors for analysis,
- analyzing resource-specific impacts for individual stressors,
- analyzing resource-specific impacts for multiple stressors,
- examining potential marine species population-level impacts,
- analyzing cumulative effects, and
- considering mitigation designed to avoid potential impacts.

Stressor: an agent, condition, or other stimulus that causes stress to an organism or alters physical, socioeconomic, or cultural resources.

Navy training and testing activities in the Proposed Action may produce one or more stimuli that cause stress on a resource. Each proposed Navy activity was examined to determine its potential stressors. The term stressor is broadly used in this document to refer to an agent, condition, or other stimulus that causes stress to an organism or alters physical, socioeconomic, or cultural resources. Not all stressors affect every resource, nor do all proposed Navy activities produce all stressors. Since the activities proposed in this EIS/OEIS are similar to current activities analyzed previously, the stressors considered are also similar.

The potential direct, indirect, and cumulative impacts of the Proposed Action were analyzed based on these potential stressors being present with the resource. Data sets used for analysis were considered across the full spectrum of Navy training and testing for the foreseeable future. For the purposes of analysis and presentation within this EIS/OEIS, data was organized and evaluated in 1-year and 5-year increments. Based upon current knowledge and the proposed training and testing, the Navy does not reasonably foresee a change to the Navy's direct and indirect impact conclusions across other time frames (e.g., 2, 7, or 10 years). Direct impacts are caused by the action and occur at the same time and place. Indirect impacts result when a direct impact on one resource induces an impact on another resource (referred to as a secondary stressor). Indirect impacts would be reasonably foreseeable because of a functional relationship between the directly impacted resource and the secondarily impacted resource. For example, a significant change in water quality could secondarily impact those resources that rely on water quality, such as marine animals and public health and safety. Cumulative effects or impacts are the incremental impacts of the action added to other past, present, and reasonably foreseeable future actions.

First, a preliminary analysis was conducted to determine the environmental resources potentially impacted and associated stressors. Secondly, each resource was analyzed for potential impacts of individual stressors (including consideration of the applicable standard operating procedures that will benefit a resource, as outlined in Section 2.3.3, Standard Operating Procedures), followed by an analysis of the combined impacts of all stressors related to the Proposed Action. A cumulative impact analysis was conducted to evaluate the incremental impact of the Proposed Action when added to other past, present, and reasonably foreseeable future actions (Chapter 4, Cumulative Impacts). Mitigation measures were considered in the analysis of each stressor (as applicable) and are discussed in detail in Chapter 5 (Mitigation), and regulatory considerations are discussed in Chapter 6 (Regulatory Considerations).

In this sequential approach, the initial analyses were used to develop each subsequent step so the analysis focused on relevant issues (defined during scoping) that warranted the most attention. The systematic nature of this approach allowed the Proposed Action with the associated stressors and potential impacts to be effectively tracked throughout the process. This approach provides a comprehensive analysis of applicable stressors and potential impacts. Each step is described in more detail below.

3.0.3.1 Resources and Issues Evaluated

Physical resources evaluated include air quality, sediments, and water quality. Biological resources (including threatened and endangered species) evaluated include vegetation, invertebrates, habitats, fishes, marine mammals, reptiles, and birds. Human resources evaluated include cultural resources, socioeconomic resources, and public health and safety.

3.0.3.2 Resources and Issues Eliminated from Further Consideration

This HSTT EIS/OEIS analyzes only in-water activities and activities occurring over water. Therefore, some resource areas are not analyzed. Resources and issues considered but not carried forward for further consideration include land use, demographics, environmental justice, and children’s health and safety. Land use was eliminated from further consideration because the offshore activities in the Proposed Action are not connected to land use issues and no new actions are being proposed that would include relevant land use. Demographics were eliminated from further consideration because the Proposed Action’s effects occur at sea away from human populations, and would not result in a change in the demographics within the Study Area or within the counties of the coastal states that abut the Study Area. Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, was eliminated as an issue for further consideration because all of the proposed activities occur in the ocean and in harbors and bays, where there are no human populations present. Therefore, there are no disproportionately high and adverse human health or environmental impacts from the Proposed Action on minority populations or low-income populations. Similarly, Executive Order 13045, *Protection of Children from Environmental Health Risks and Safety Risks*, was eliminated as an issue for further consideration because all of the proposed activities occur in the ocean, where there are no child populations present. Therefore, the Proposed Action would not lead to disproportionate risks to children that result from environmental health risks or safety risks.

3.0.3.3 Identifying Stressors for Analysis

The proposed training and testing activities were evaluated to identify specific components that could act as stressors by having direct or indirect impacts on the environment. This analysis considers the locations where activities may occur (i.e., spatial variation). Matrices were prepared to identify associations between stressors, resources, and the spatial relationships of those stressors, resources, and activities within the Study Area under the Proposed Action. Each stressor includes a description of activities that may generate the stressor. Additional information on these activities and resources are also provided in Appendix B (Activity Stressor Matrices). Stressors for physical resources (air quality, sediments and water quality) and human resources (cultural resources, socioeconomic resources, and public health and safety) are described in their respective sections of Chapter 3 (Affected Environment and Environmental Consequences).

A preliminary analysis identified the stressor/resource interactions that warrant further analysis in the EIS/OEIS based on public comments received during scoping, previous NEPA analyses, and opinions of subject matter experts. Stressor/resource interactions that were determined to have negligible or no impacts were not carried forward for analysis in the EIS/OEIS. For example, some fixed-wing carrier-based aircraft may jettison fuel prior to an arrested landing to adjust their gross weight to a safe level. However, the fuel is jettisoned at altitudes and airspeeds that evaporate and atomize it before it reaches the water's surface (Air Force Engineering and Services Center, 1981), resulting in no detectable impact to air or water quality.

In subsequent sections, tables are provided in which the annual number of events that could involve a particular stressor are totaled by alternative and by location, within the categories of training and testing. For example, see Table 3.0-13 (Events Including Electromagnetic Devices). It is important to note that the various tables are not exclusive of each other, and that the stressors from a single named activity from Chapter 2 (Description of Proposed Action and Alternatives) could show up on several tables. For example, the activity Anti-Submarine Warfare Tracking Exercise – Helicopter could include acoustic stressors that would appear on Table 3.0-1, physical disturbance stressors (Table 3.0-24), strike stressors (Table 3.0-28), entanglement stressors (Table 3.0-29), and ingestion stressors (Tables 3.0-18–21, 24–25, 31–34). Also, activities are not always conducted independently of each other. For example, there are instances where a training activity could occur on a vessel while another training activity or a testing activity is being conducted on the same vessel simultaneously. Finally, note that some of the tables that follow in this section count individual items expended (e.g., Table 3.0-19) while others count the annual number of events in which that stressor could occur at least once during the conduct of that activity (e.g., Table 3.0-16).

3.0.3.3.1 Acoustic Stressors

This section describes the characteristics of sounds produced during naval training and testing and the relative magnitude and location of these sound-producing activities. This provides the basis for analysis of acoustic impacts on resources in the remainder of Chapter 3 (Affected Environment and Environmental Consequences). Explanations of the terminology and metrics used when describing sound in this EIS/OEIS are in Appendix D (Acoustic and Explosive Concepts).

Acoustic stressors include acoustic signals emitted into the water for a specific purpose (by, e.g., active sonars and air guns), as well as incidental sources of broadband sound produced as a byproduct of vessel movement, aircraft transits, pile driving and removal, and use of weapons or other deployed objects. Explosives also produce broadband sound but are characterized separately from other acoustic sources due to their unique hazardous characteristics (see Section 3.0.3.3.2, Explosive Stressors). Characteristics of each of these sound sources are described in the following sections.

In order to better organize and facilitate the analysis of approximately 300 individual sources of underwater sound deliberately employed by the Navy including sonars, other transducers (devices that convert energy from one form to another, in this case to sound waves), air guns, and explosives, a series of source classifications, or source bins, were developed. The source classification bins do not include the broadband sounds produced incidental to pile driving, vessel and aircraft transits, and weapons firing.

The use of source classification bins provides the following benefits:

- Provides the ability for new sensors or munitions to be covered under existing authorizations, as long as those sources fall within the parameters of a "bin;"
- Improves efficiency of source utilization data collection and reporting requirements anticipated under the MMPA authorizations;
- Ensures a conservative approach to all impact estimates, as all sources within a given class are modeled as the most impactful source (highest source level, longest duty cycle, or largest net explosive weight) within that bin;
- Allows analyses to be conducted in a more efficient manner, without any compromise of analytical results; and
- Provides a framework to support the reallocation of source usage (hours/explosives) between different source bins, as long as the total numbers of takes remain within the overall analyzed and authorized limits. This flexibility is required to support evolving Navy training and testing requirements, which are linked to real world events.

3.0.3.3.1.1 Sonar and Other Transducers

Active sonar and other transducers emit non-impulsive sound waves into the water to detect objects, safely navigate, and communicate. Passive sonars differ from active sound sources in that they do not emit acoustic signals; rather, they only receive acoustic information about the environment, or listen. In this EIS/OEIS, the terms sonar and other transducers will be used to indicate active sound sources unless otherwise specified.

The Navy employs a variety of sonars and other transducers to obtain and transmit information about the undersea environment. Some examples are mid-frequency hull-mounted sonars used to find and track potential enemy submarines; high-frequency small object detection sonars used to detect mines; high-frequency underwater modems used to transfer data over short ranges; and extremely high-frequency (greater than 200 kilohertz [kHz]) Doppler sonars used for navigation, like those used on commercial and private vessels. The characteristics of these sonars and other transducers, such as source level, beam width, directivity, and frequency, depend on the purpose of the source. Higher frequencies can carry more information or provide more information about objects off which they reflect, but attenuate more rapidly. Lower frequencies attenuate less rapidly, so may detect objects over a longer distance, but with less detail.

Propagation of sound produced underwater is highly dependent on environmental characteristics such as bathymetry, bottom type, water depth, temperature, and salinity. The sound received at a particular location will be different than near the source due to the interaction of many factors, including propagation loss; how the sound is reflected, refracted, or scattered; the potential for reverberation; and interference due to multi-path propagation. In addition, absorption greatly affects the distance over which higher frequency sounds propagate. The effects of these factors are explained in Appendix D (Acoustic and Explosive Concepts). Because of the complexity of analyzing sound propagation in the ocean environment, the Navy relies on acoustic models in its environmental analyses that consider sound source characteristics and varying ocean conditions across the Study Area.

The sound sources and platforms typically used in naval activities analyzed in the EIS/OEIS are described in Appendix A (Navy Activity Descriptions). Sonars and other transducers used to obtain and transmit information underwater during Navy training and testing activities generally fall into several categories of use described below.

Anti-Submarine Warfare

Sonar used during anti-submarine warfare would impart the greatest amount of acoustic energy of any category of sonar and other transducers analyzed in this EIS/OEIS. Types of sonars used to detect potential enemy vessels include hull-mounted, towed, line array, sonobuoy, helicopter dipping, and torpedo sonars. In addition, acoustic targets and decoys (countermeasures) may be deployed to emulate the sound signatures of vessels or repeat received signals.

Most anti-submarine warfare sonars are mid-frequency (1–10 kHz) because mid-frequency sound balances sufficient resolution to identify targets with distance over which threats can be identified. However, some sources may use higher or lower frequencies. Duty cycles can vary widely, from rarely used to continuously active. Anti-submarine warfare sonars can be wide-angle in a search mode or highly directional in a track mode.

Most anti-submarine warfare activities involving submarines or submarine targets would occur in waters greater than 600 feet (ft.) deep due to safety concerns about running aground at shallower depths. Sonars used for anti-submarine warfare activities would typically be used beyond 12 nautical miles (NM) from shore. Exceptions include use of dipping sonar by helicopters; maintenance of systems while in port; and system checks while transiting to or from port.

Mine Warfare, Small Object Detection, and Imaging

Sonars used to locate mines and other small objects, as well those used in imaging (e.g., for hull inspections or imaging of the seafloor), are typically high-frequency or very high frequency. Higher frequencies allow for greater resolution and, due to their greater attenuation, are most effective over shorter distances. Mine detection sonar can be deployed (towed or vessel hull-mounted) at variable depths on moving platforms (ships, helicopters, or unmanned vehicles) to sweep a suspected mined area. Hull-mounted anti-submarine sonars can also be used in an object detection mode known as “Kingfisher” mode. Sonars used for imaging are usually used in close proximity to the area of interest, such as pointing downward near the seafloor.

Mine detection sonar use would be concentrated in areas where practice mines are deployed, typically in water depths less than 200 ft. and at established training minefields, temporary minefields close to strategic ports and harbors, or at targets of opportunity such as navigation buoys. Kingfisher mode on vessels is most likely to be used when transiting to and from port. Sound sources used for imaging could be used throughout the Study Area.

Navigation and Safety

Similar to commercial and private vessels, Navy vessels employ navigational acoustic devices including speed logs, Doppler sonars for ship positioning, and fathometers. These may be in use at any time for safe vessel operation. These sources are typically highly directional to obtain specific navigational data.

Communication

Sound sources used to transmit data (such as underwater modems), provide location (pingers), or send a single brief release signal to bottom-mounted devices (acoustic release) may be used throughout the Study Area. These sources typically have low duty cycles and are usually only used when it is desirable to send a detectable acoustic message.

Classification of Sonar and Other Transducers

Sonars and other transducers are grouped into classes that share an attribute, such as frequency range or purpose of use. Below, classes are further sorted by bins based on the frequency or bandwidth; source level; and, when warranted, the application in which the source would be used. Unless stated otherwise, a reference distance of 1 meter is used for sonar and other transducers.

- Frequency of the non-impulsive acoustic source:
  - Low-frequency sources operate below 1 kHz
  - Mid-frequency sources operate at and above 1 kHz, up to and including 10 kHz
  - High-frequency sources operate above 10 kHz, up to and including 100 kHz
  - Very high frequency sources operate above 100 kHz but below 200 kHz
- Sound pressure level:
  - Greater than 160 dB re 1 µPa, but less than 180 dB re 1 µPa
  - Equal to 180 dB re 1 µPa and up to 200 dB re 1 µPa
  - Greater than 200 dB re 1 µPa
- Application in which the source would be used:
  - Sources with similar functions that have similar characteristics, such as pulse length (duration of each pulse), beam pattern, and duty cycle

The bins used for classifying active sonars and transducers that are quantitatively analyzed in the Study Area are shown in Table 3.0-1. While general parameters or source characteristics are shown in the table, actual source parameters are classified.

Table 3.0-1 shows the bin use that could occur in any year under each action alternative for training and testing activities. A range of annual bin use indicates that use of that bin is anticipated to vary annually, consistent with the variation in the number of annual activities described in Chapter 2 (Description of Proposed Action and Alternatives). The 5-year total for both action alternatives takes that variability into account.

There are in-water active acoustic sources with narrow beam widths, downward directed transmissions, short pulse lengths, frequencies above known hearing ranges, low source levels, or combinations of these factors, which are not anticipated to result in takes of protected species. These sources are categorized as *de minimis* sources and are qualitatively analyzed to determine the appropriate determinations under NEPA in the appropriate resource impact analyses, as well as under the MMPA, and the ESA. When used during routine training and testing activities, and in a typical environment, *de minimis* sources fall into one or more of the following categories:

- <u>Transmit primarily above 200 kHz</u>: Sources above 200 kHz are above the hearing range of the most sensitive marine mammals and far above the hearing range of any other animals in the Study Area.
- <u>Source levels of 160 dB re 1 µPa or less</u>: Low-powered sources with source levels less than 160 dB re 1 µPa are typically hand-held sonars, range pingers, transponders, and acoustic communication devices. Assuming spherical spreading for a 160 dB re 1 µPa source, the sound will attenuate to less than 140 dB re 1 µPa within 10 m and less than 120 dB re 1 µPa within 100 m of the source. Ranges would be even shorter for a source less than 160 dB re 1 µPa source level.

Table 3.0-1: Sonar and Transducer Sources Quantitatively Analyzed

Source Class Category	Bin	Description	Unit[1]	Training				Testing			
				Alternative 1		Alternative 2		Alternative 1		Alternative 2	
				Annual[2]	5-year Total	Annual[2]	5-year Total	Annual[2]	5-year Total	Annual[2]	5-year Total
Low-Frequency (LF): Sources that produce signals less than 1 kHz	LF3	LF sources greater than 200 dB	H	0	0	0	0	195	975	195	975
	LF4	LF sources equal to 180 dB and up to 200 dB	H	0	0	0	0	589–777	3,131	777	3,883
			C	0	0	0	0	20	100	20	100
	LF5	LF sources less than 180 dB	H	0	0	0	0	1,814–2,694	9,950	2,694	13,470
	LF6	LF sources greater than 200 dB with long pulse lengths	H	121–167	668	183	913	40–80	240	80	400
Mid-Frequency (MF): Tactical and non-tactical sources that produce signals between 1 and 10 kHz	MF1	Hull-mounted surface ship sonars (e.g., AN/SQS-53C and AN/SQS-61)	H	5,779–6,702	28,809	8,268–8,304	39,883	1,540	5,612	1,540	5,612
	MF1K	Kingfisher mode associated with MF1 sonars	H	100	500	100	500	14	70	14	70
	MF2[3]	Hull-mounted surface ship sonars (e.g., AN/SQS-56)	H	0	0	0	0	54	270	54	270
	MF3	Hull-mounted submarine sonars (e.g., AN/BQQ-10)	H	2,080–2,175	10,440	2,185–2,191	10,815	1,311	6,553	1,311	6,553
	MF4	Helicopter-deployed dipping sonars (e.g., AN/AQS-22 and AN/AQS-13)	H	414–489	2,070	488–489	2,296	311–475	1,717	475	2,374

Table 3.0-1: Sonar and Transducer Sources Quantitatively Analyzed (continued)

Source Class Category	Bin	Description	Unit[1]	Training				Testing			
				Alternative 1		Alternative 2		Alternative 1		Alternative 2	
				Annual[2]	5-year Total	Annual[2]	5-year Total	Annual[2]	5-year Total	Annual[2]	5-year Total
Mid-Frequency (MF): Tactical and non-tactical sources that produce signals between 1 and 10 kHz (continued)	MF5	Active acoustic sonobuoys (e.g., DICASS)	C	5,704–6,124	28,300	6,176–6,236	30,160	5,250–5,863	27,120	6,063	30,107
	MF6	Active underwater sound signal devices (e.g., MK 84)	C	9	45	9	45	1,141–1,226	5,835	1,276	6,340
	MF8	Active sources (greater than 200 dB) not otherwise binned	H	0	0	0	0	70	350	70	350
	MF9	Active sources (equal to 180 dB and up to 200 dB) not otherwise binned	H	0	0	0	0	5,139–5,165	25,753	5,139–5,165	25,753
	MF10	Active sources (greater than 160 dB, but less than 180 dB) not otherwise binned	H	0	0	0	0	1,824–1,992	9,288	1,992	9,960
	MF11	Hull-mounted surface ship sonars with an active duty cycle greater than 80%	H	718–890	3,597	1,082	5,185	56	280	56	280

Table 3.0-1: Sonar and Transducer Sources Quantitatively Analyzed (continued)

Source Class Category	Bin	Description	Unit[1]	Training				Testing			
				Alternative 1		Alternative 2		Alternative 1		Alternative 2	
				Annual[2]	5-year Total	Annual[2]	5-year Total	Annual[2]	5-year Total	Annual[2]	5-year Total
Mid-Frequency (MF): Tactical and non-tactical sources that produce signals between 1 and 10 kHz (continued)	MF12	Towed array surface ship sonars with an active duty cycle greater than 80%	H	161–215	884	251	1,253	660	3,300	660	3,300
	MF13	MF sonar source	H	0	0	0	0	300	1,500	300	1,500
High-Frequency (HF): Tactical and non-tactical sources that produce signals between 10 and 100 kHz	HF1	Hull-mounted submarine sonars (e.g., AN/BQQ-10)	H	1,795–1,816	8,939	1,810–1,816	8,987	772	3,859	772	3,859
	HF2	HF Marine Mammal Monitoring System	H	0	0	0	0	120	600	120	600
	HF3	Other hull-mounted submarine sonars (classified)	H	287	1,345	287	1,345	110	549	110	549
	HF4	Mine detection, classification, and neutralization sonar (e.g., AN/SQS-20)	H	2,316	10,380	2,316	10,380	16,299–16,323	81,447	16,335	81,602
	HF5	Active sources (greater than 200 dB) not otherwise binned	H	0	0	0	0	960	4,800	960	4,800
			C	0	0	0	0	40	200	40	200

Table 3.0-1: Sonar and Transducer Sources Quantitatively Analyzed (continued)

Source Class Category	Bin	Description	Unit[1]	Training				Testing			
				Alternative 1		Alternative 2		Alternative 1		Alternative 2	
				Annual[2]	5-year Total	Annual[2]	5-year Total	Annual[2]	5-year Total	Annual[2]	5-year Total
High-Frequency (HF): Tactical and non-tactical sources that produce signals between 10 and 100 kHz (continued)	HF6	Active sources (equal to 180 dB and up to 200 dB) not otherwise binned	H	0	0	0	0	1,000–1,009	5,007	1,009	5,043
	HF7	Active sources (greater than 160 dB, but less than 180 dB) not otherwise binned	H	0	0	0	0	1,380	6,900	1,380	6,900
	HF8	Hull-mounted surface ship sonars (e.g., AN/SQS-61)	H	118	588	118	588	1,032	3,072	1,032	3,072
Anti-Submarine Warfare (ASW): Tactical sources (e.g., active sonobuoys and acoustic countermeasures systems) used during ASW training and testing activities	ASW1	MF systems operating above 200 dB	H	194–261	1,048	293	1,465	470	2,350	470	2,350
	ASW2	MF Multistatic Active Coherent sonobuoy (e.g., AN/SSQ-125)	C	688–790	3,346	818	3,820	4,334–5,191	23,375	5,691	28,455
	ASW3	MF towed active acoustic countermeasure systems (e.g., AN/SLQ-25)	H	5,005–6,425	25,955	7,598–7,622	37,108	2,741	13,705	2,741	13,705

Table 3.0-1: Sonar and Transducer Sources Quantitatively Analyzed (continued)

Source Class Category	*Bin*	*Description*	*Unit*[1]	*Training*				*Testing*			
				Alternative 1		*Alternative 2*		*Alternative 1*		*Alternative 2*	
				Annual[2]	*5-year Total*	*Annual*[2]	*5-year Total*	*Annual*[2]	*5-year Total*	*Annual*[2]	*5-year Total*
Anti-Submarine Warfare (ASW): Tactical sources (e.g., active sonobuoys and acoustic countermeasures systems) used during ASW training and testing activities (continued)	ASW4	MF expendable active acoustic device countermeasures (e.g., MK 3)	C	1,284–1,332	6,407	1,320–1,332	6,519	2,244	10,910	2,244	10,910
	ASW5[3]	MF sonobuoys with high duty cycles	H	220–300	1,260	300	1,500	522–592	2,740	652	3,260
Torpedoes (TORP): Source classes associated with the active acoustic signals produced by torpedoes	TORP1	Lightweight torpedo (e.g., MK 46, MK 54, or Anti-Torpedo Torpedo)	C	231–237	1,137	231–237	1,137	923–971	4,560	964–971	4,683
	TORP2	Heavyweight torpedo (e.g., MK 48)	C	521–587	2,407	521–587	2,407	404	1,948	404	1,948
	TORP3		C	0	0	0	0	45	225	45	225

Table 3.0-1: Sonar and Transducer Sources Quantitatively Analyzed (continued)

Source Class Category	*Bin*	*Description*	*Unit[1]*	*Training*				*Testing*			
				Alternative 1		*Alternative 2*		*Alternative 1*		*Alternative 2*	
				Annual[2]	*5-year Total*	*Annual[2]*	*5-year Total*	*Annual[2]*	*5-year Total*	*Annual[2]*	*5-year Total*
Forward Looking Sonar (FLS): Forward or upward looking object avoidance sonars used for ship navigation and safety	FLS2	HF sources with short pulse lengths, narrow beam widths, and focused beam patterns	H	28	140	28	140	448–544	2,432	448–544	2,432
	FLS3	VHF sources with short pulse lengths, narrow beam widths, and focused beam patterns	H	0	0	0	0	2,640	13,200	2,640	13,200
Acoustic Modems (M): Systems used to transmit data through the water	M3	MF acoustic modems (greater than 190 dB)	H	61	153	61	153	518	2,588	518	2,588
Swimmer Detection Sonars (SD): Systems used to detect divers and submerged swimmers	SD1–SD2	HF and VHF sources with short pulse lengths, used for the detection of swimmers and other objects for the purpose of port security	H	0	0	0	0	10	50	10	50

Table 3.0-1: Sonar and Transducer Sources Quantitatively Analyzed (continued)

Source Class Category	*Bin*	*Description*	*Unit*[1]	*Training*				*Testing*			
				Alternative 1		*Alternative 2*		*Alternative 1*		*Alternative 2*	
				Annual[2]	*5-year Total*	*Annual*[2]	*5-year Total*	*Annual*[2]	*5-year Total*	*Annual*[2]	*5-year Total*
Synthetic Aperture Sonars (SAS): Sonars in which active acoustic signals are post-processed to form high-resolution images of the seafloor	SAS1	MF SAS systems	H	0	0	0	0	1,960	9,800	1,960	9,800
	SAS2	HF SAS systems	H	900	4,498	900	4,498	8,584	42,920	8,584	42,920
	SAS3	VHF SAS systems	H	0	0	0	0	4,600	23,000	4,600	23,000
	SAS4	MF to HF broadband mine countermeasure sonar	H	42	210	42	210	0	0	0	0
Broadband Sound Sources (BB): Sonar systems with large frequency spectra, used for various purposes	BB4	LF to MF oceanographic source	H	0	0	0	0	810–1,170	4,434	810–1,170	4,434
	BB7	LF oceanographic source	C	0	0	0	0	28	140	28	140
	BB9	MF optoacoustic source	H	0	0	0	0	480	2,400	480	2,400

[1]H = hours; C = count (e.g., number of individual pings or individual sonobuoys)
[2]Expected annual use may vary per bin because the number of events may vary from year to year, as described in Chapter 2 (Description of Proposed Action and Alternatives).
[3]Formerly ASW2 (H) in Phase II.
Note: dB = decibel(s), kHz = kilohertz

- Acoustic source classes listed in Table 3.0-2: Sources with operational characteristics, such as short pulse length, narrow beam width, downward-directed beam, and low energy release, or manner of system operation, which exclude the possibility of any significant impact to a protected species (actual source parameters are classified). Even if there is a possibility that some species may be exposed to and detect some of these sources, any response is expected to be short-term and inconsequential.

Table 3.0-2: Sonar and Transducers Qualitatively Analyzed

Source Class Category	*Bin*	*Characteristics*
Broadband Sound Sources (BB): Sources with wide frequency spectra	BB3	• very high frequency • very short pulse length
	BB8	• small imploding source (light bulb)
Doppler Sonar/Speed Logs (DS): High-frequency/very high frequency navigation transducers	DS2–DS4	*Required for safe navigation* • downward focused • narrow beam width • very short pulse lengths
Fathometers (FA): High-frequency sources used to determine water depth	FA1–FA4	*Required for safe navigation* • downward focused directly below the vessel • narrow beam width (typically much less than 30º) • short pulse lengths (less than 10 milliseconds)
Hand-Held Sonar (HHS): High-frequency sonar devices used by Navy divers for object location	HHS1	• very high frequency sound at low power levels • narrow beam width • short pulse lengths • under control of the diver (power and direction)
Imaging Sonar (IMS): Sonars with high or very high frequencies used to obtain images of objects underwater	IMS1–IMS3	• High-frequency or very high frequency • downward directed • narrow beam width • very short pulse lengths (typically 20 milliseconds)
High-Frequency Acoustic Modems (M): Systems that send data underwater **Tracking Pingers (P):** Devices that send a ping to identify an object location	M2 P1–P4	• low duty cycles (single pings in some cases) • short pulse lengths (typically 20 milliseconds) • low source levels
Acoustic Releases (R): Systems that ping to release a bottom-mounted object from its housing in order to retrieve the device at the surface	R1–R3	• typically emit only several pings to send release order
Side-Scan Sonars (SSS): Sonars that use active acoustic signals to produce high-resolution images of the seafloor	SSS1–SSS2	• downward-directed beam • short pulse lengths (less than 20 milliseconds)

Notes: º = degree(s), kHz= kilohertz, lb. = pound(s)

3.0.3.3.1.2 Air Guns

Air guns are essentially stainless steel tubes charged with high-pressure air via a compressor. An impulsive sound is generated when the air is almost instantaneously released into the surrounding water. Small air guns with capacities up to 60 cubic inches would be used during testing activities in the off-shore areas of the Southern California Range Complex and in the Hawaii Range Complex. Table 3.0-3 shows the number of air gun shots proposed in the HSTT Study Area.

Generated impulses would have short durations, typically a few hundred milliseconds, with dominant frequencies below 1 kHz. The root-mean-square sound pressure level (SPL) and peak pressure (SPL peak) at a distance 1 m from the air gun would be approximately 215 dB re 1 µPa and 227 dB re 1 µPa, respectively, if operated at the full capacity of 60 cubic inches. The size of the air gun chamber can be adjusted, which would result in lower SPLs and sound exposure level (SEL) per shot.

For the specific applications and use of air guns in the HSTT Study Area, air guns were analyzed based on 1 and 10 firings. Ten firings of an air gun was a conservative estimate of the number of firings that could occur over a single exposure duration at a single location.

Table 3.0-3: Training and Testing Air Gun Sources Quantitatively Analyzed in the Study Area

Source Class Category	*Bin*	*Unit*[1]	*Training*				*Testing*			
			Alternative 1		*Alternative 2*		*Alternative 1*		*Alternative 2*	
			Annual	*5-year Total*	*Annual*	*5-year Total*	*Annual*	*5-year Total*	*Annual*	*5-year Total*
Air Guns (AG): small underwater air guns	AG	C	0	0	0	0	844	4,220	844	4,220

[1] C = count. One count (C) of AG is equivalent to 100 air gun firings.

3.0.3.3.1.3 Pile Driving

Impact pile driving and vibratory pile removal would occur during training for the construction of an Elevated Causeway System, a temporary pier that allows the offloading of ships in areas without a permanent port.

Installing piles for elevated causeways would involve the use of an impact hammer mechanism with both it and the pile held in place by a crane. The hammer rests on the pile, and the assemblage is then placed in position vertically on the beach or, when offshore, positioned with the pile in the water and resting on the seafloor. When the pile driving starts, the hammer part of the mechanism is raised up and allowed to fall, transferring energy to the top of the pile. The pile is thereby driven into the sediment by a repeated series of these hammer blows. Each blow results in an impulsive sound emanating from the length of the pile into the water column as well as from the bottom of the pile through the sediment. Because the impact wave travels through the steel pile at speeds faster than the speed of sound in water, a steep-fronted acoustic shock wave is formed in the water (note this shock wave has very low peak pressure compared to a shock wave from an explosive) (Reinhall & Dahl, 2011). An impact pile driver generally operates on average 35 blows per minute.

Pile removal involves the use of vibratory extraction, during which the vibratory hammer is suspended from the crane and attached to the top of a pile. The pile is then vibrated by hydraulic motors rotating eccentric weights in the mechanism, causing a rapid up and down vibration in the pile. This vibration causes the sediment particles in contact with the pile to lose frictional grip on the pile. The crane slowly lifts up on the vibratory driver and pile until the pile is free of the sediment. Vibratory removal creates continuous non-impulsive noise at low source levels for a short duration.

The source levels of the noise produced by impact pile driving and vibratory pile removal from an actual elevated causeway pile driving and removal are shown in Table 3.0-4.

In addition to underwater noise, the installation and removal of piles also results in airborne noise in the environment. Impact pile driving creates in-air impulsive sound about 100 dBA re 20 µPa at a range of 15 m (Illingworth and Rodkin, 2015, 2017). During vibratory extraction, the three aspects that generate airborne noise are the crane, the power plant, and the vibratory extractor. The average sound level recorded in air during vibratory extraction was about 85 dBA re 20 µPa (94 dB re 20 µPa) within a range of 10 to 15 m (Illingworth and Rodkin, 2015).

Table 3.0-4: Elevated Causeway System Pile Driving and Removal Underwater Sound Levels

Pile Size &Type	*Method*	*Average Sound Levels at 10 m (SEL per individual pile)*
24-in. Steel Pipe Pile	Impact[1]	192 dB re 1 µPa SPL peak 182 dB re 1 $\mu Pa^2 s$ SEL (single strike)
24-in. Steel Pipe Pile	Vibratory[2]	146 dB re 1 µPa SPL rms 145 dB re 1 $\mu Pa^2 s$ SEL (per second of duration)

[1]Illingworth and Rodkin (2017), [2]Illingworth and Rodkin (2015)
Notes: in. = inch, SEL = Sound Exposure Level, SPL = Sound Pressure Level,
rms = root mean squared, dB re 1 µPa = decibels referenced to 1 micropascal

The length of the pier, and therefore the number of piles required, would be determined by the distance from shore to the appropriate water depth for ship off-loading. During training exercises, Elevated Causeway System construction is continued until personnel become proficient in the operation of the pile driving equipment and construction techniques. The size of the pier and number of piles used in an Elevated Causeway System training event is assumed to be no greater than 1,520 ft. long, requiring 119 supporting piles. Construction of the Elevated Causeway System would involve intermittent impact pile driving over approximately 20 days. Crews work 24 hours a day and would drive approximately six piles in that period. Each pile takes about 15 minutes to drive with time taken between piles to reposition the driver. When training events that use the Elevated Causeway System are complete, the structure would be removed using vibratory methods over approximately 10 days. Crews would remove about 12 piles per 24-hour period, each taking about six minutes to remove. Table 3.0-5 summarizes the pile driving and pile removal activities that would occur during a 24-hour period.

Table 3.0-5: Summary of Pile Driving and Removal Activities per 24-Hour Period

Method	Piles Per 24-Hour Period	Time Per Pile	Total Estimated Time of Noise Per 24-Hour Period
Pile Driving (Impact)	6	15 minutes	90 minutes
Pile Removal (Vibratory)	12	6 minutes	72 minutes

Pile driving for the Elevated Causeway System would occur in shallower water, and sound could be transmitted on direct paths through the water, be reflected at the water surface or bottom, or travel through bottom substrate. Soft substrates such as sand bottom at the proposed elevated causeway system locations would absorb or attenuate the sound more readily than hard substrates (rock), which may reflect the acoustic wave. Most acoustic energy would be concentrated below 1,000 hertz (Hz)

(Hildebrand, 2009). Construction of the elevated causeway could occur in sandy shallow water coastal areas at Silver Strand Training Complex and at Camp Pendleton, both in the Southern California Range Complex.

3.0.3.3.1.4 Vessel Noise

Vessel noise, in particular commercial shipping, is a major contributor to noise in the ocean and inshore waters. Frisk (2012) reported that between 1950 and 2007 ocean noise in the 25–50 Hz frequency range has increased 3.3 dB per decade, resulting in a cumulative increase of approximately 19 dB over a baseline of 52 dB. The increase in noise is associated with an increase in commercial shipping, which correlates with global economic growth (Frisk, 2012). Naval vessels (including ships and small craft) and civilian vessels (commercial ships, tugs, work boats, pleasure craft) produce low-frequency, broadband underwater sound, though the exact level of noise produced varies by vessel type. However, within the HSTT Study Area, Navy vessels represent a small amount of overall vessel traffic and an even smaller amount of overall vessel traffic noise. As shown in Table 3.0-6 and Figure 3.0-10, Navy ships make up only 8 percent of total ship traffic in Hawaii, and only 4 percent of total ship traffic in Southern California (Mintz, 2016). In terms of anthropogenic noise, Navy ships are engineered to be as quiet as possible given ship class limitations, and would contribute a correspondingly smaller amount of shipping noise compared to more common commercial shipping and boating (Mintz & Filadelfo, 2011; Mintz, 2012). Exposure to vessel noise would be greatest in the areas of highest vessel traffic. Within the Study Area, commercial traffic is heaviest along the coast of California and near the major Hawaiian Islands (Mintz, 2012).

Table 3.0-6: Interpolated Ship-Hours from 2011 to 2015 Positional Records in the Study Area

Ship Category	***HRC Vicinity***	***SOCAL Vicinity***
U.S. Navy	358,000	1,076,000
U.S. Coast Guard	42,000	138,000
Foreign Military	68,000	56,000
Nonmilitary	3,903,000	27,223,000

Note: Interpolated SeaLink data from 2011 through 2015 which represents an unknown fraction of actual vessel traffic. This data represents a relative traffic level, not absolute ship presence (Mintz, 2016)

While commercial traffic (and, therefore, broadband noise generated by it) is relatively steady throughout the year, Navy traffic is episodic in the ocean. Vessels engaged in training and testing may consist of a single vessel involved in unit-level activity for a few hours or multiple vessels involved in a major training exercise that could last a few weeks within a given area. Activities involving vessel movements occur intermittently and are variable in duration. Navy vessels do contribute to the overall increased ambient noise in inland waters near Navy ports, although their contribution to the overall noise in these environments is a small percentage compared to the large amounts of commercial and recreational vessel traffic in these areas (Mintz & Filadelfo, 2011). Anti-submarine warfare surface combatants (such as guided missile destroyers and cruisers) and submarines make up a large part of Navy traffic but contribute little noise to the overall sound budget of the oceans as these vessels are designed to be quiet to minimize detection. These vessels are much quieter than Navy oil tankers, for example, which have a smaller presence but contribute substantially more broadband noise (Mintz & Filadelfo, 2011).

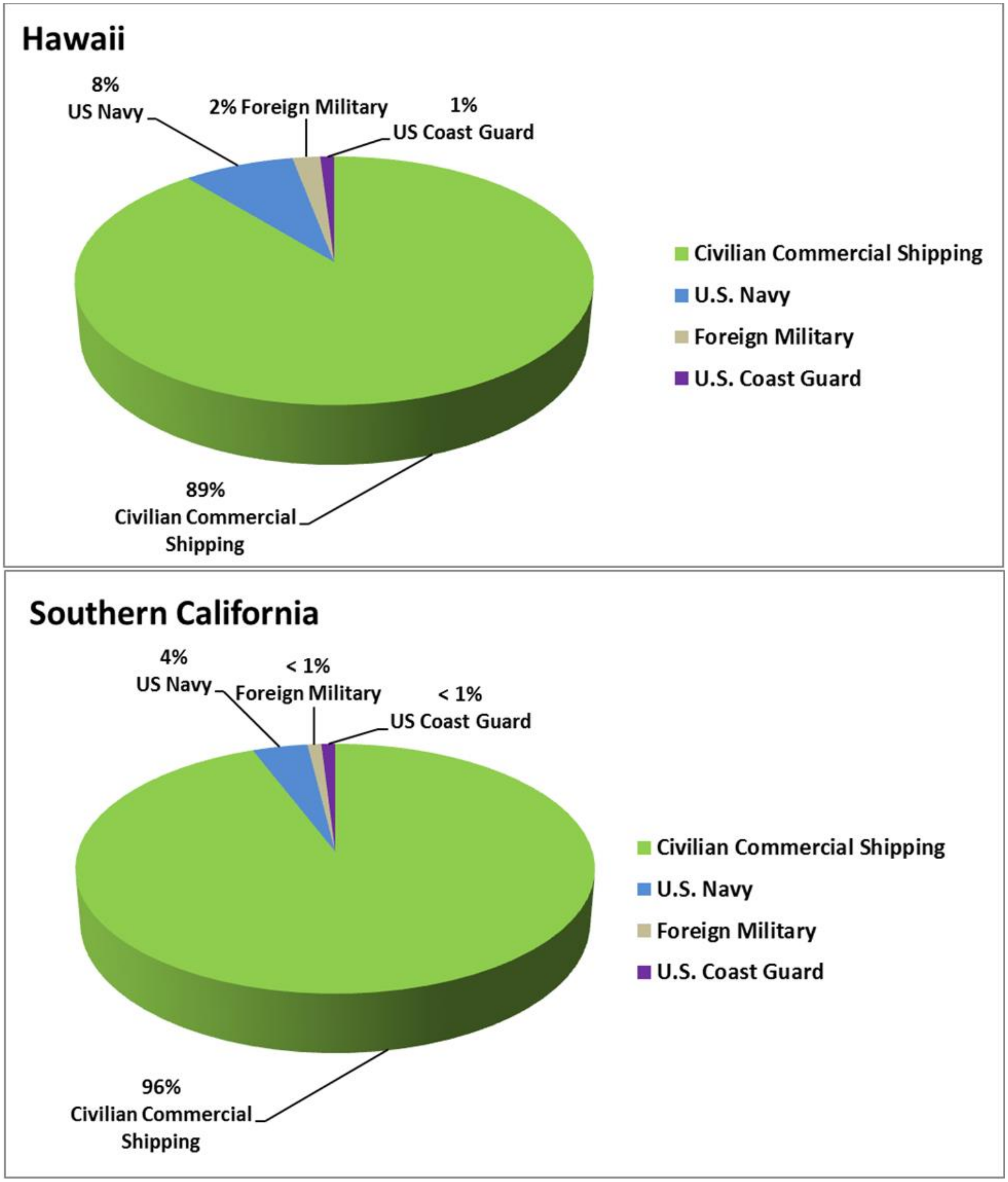

Figure 3.0-10: HSTT Surface Ship Traffic By Percent Ship-Hours 2011-2015

A variety of smaller craft that vary in size and speed, such as service vessels for routine operations and opposition forces used during training and testing events, would be operating within the Study Area.

Studies to determine traffic patterns of Navy and non-Navy vessels in the Study Area were conducted by the Center for Naval Analyses (Mintz & Parker, 2006; Mintz & Filadelfo, 2011; Mintz, 2012). The most recent analysis covered the period 2011-2015 (Mintz, 2016) and included U.S. Navy surface ship traffic and non-military vessels such as cargo vessels, bulk carriers, commercial fishing vessels, oil tankers, passenger vessels, tugs, and research vessels. Caveats to this analysis include that only vessels over 65 ft. in length are reported so smaller Navy vessels and civilian craft are not included, and vessel position records are much more frequent for Navy vessels than for commercial vessels. Therefore, the Navy is likely overrepresented in the data and the reported fraction of total energy is likely the upper limit of its contribution (Mintz & Filadelfo, 2011; Mintz, 2012).

During training and testing, speeds of most large naval vessels (greater than 60 ft.) generally range from 10 to 15 knots to limit fuel consumption; however, ships will, on occasion, operate at higher speeds within their specific operational capabilities. Mintz (2016) reported median speeds for U.S. Navy vessel and various commercial ship classes (Table 3.0-7) in the HSTT Study Area from 2011 to 2015. Radiated noise from ships varies depending on the nature, size, and speed of the ship. Due to the large number of variables that determine the sound level radiated from vessels, this source will be analyzed qualitatively. The quietest Navy warships radiate much less broadband noise than a typical fishing vessel, while the loudest Navy ships during travel are almost on par with large oil tankers (Mintz & Filadelfo, 2011). For comparison, McKenna et al. (2012) determined that container ships transiting Southern California produced broadband source levels around 188 dB re 1 µPa and a typical fishing vessel radiates noise at a source level of about 158 dB re 1 µPa (Mintz & Filadelfo, 2011; Richardson et al., 1995; Urick, 1983). The average acoustic signature for a Navy vessel is 163 dB re 1 µPa, while the average acoustic signature for a commercial vessel is 175 dB re 1 µPa (Mintz & Filadelfo, 2011). Typical large vessel ship-radiated noise is dominated by tonals related to blade and shaft sources at frequencies below 50 Hz and by broadband components related to cavitation and flow noise at higher frequencies (approximately around the one-third octave band centered at 100 Hz) (Mintz & Filadelfo, 2011; Richardson et al., 1995; Urick, 1983). Ship types also have unique acoustic signatures characterized by differences in dominant frequencies. Bulk carrier noise is predominantly near 100 Hz while container ship and tanker noise is predominantly below 40 Hz (McKenna et al., 2012). Small craft will emit higher frequency noise (between 1 kHz and 50 kHz) than larger ships (below 1 kHz). Sound produced by vessels will typically increase with speed.

Table 3.0-7: Median Surface Ship Speeds for Hawaii and Southern California 2011–2015

Ship Class	***Median Ship Speed (knots)***	
	Hawaii	***Southern California***
U.S. Navy Aircraft Carrier	17.1	15.6
U.S. Navy Cruiser or Destroyer	14.2–15.0	11.0–11.8
U.S. Navy Amphibious Assault Ship	14.9–16.0	8.8–11.1
Commercial Cargo Ship	13.2	13.4
Commercial Tanker	10.6	11.6
Passenger Ship	10.5	8.1

From Mintz (2016) who used median values to minimize erroneous and outlier data in the original data sources

Figure 3.0-11 through Figure 3.0-14 show the geographic distribution of commercial and Navy shipping in Hawaii and Southern California derived from the analysis in Mintz (2016). In Hawaii, (Mintz, 2016) shows the geographic distribution of highest Navy surface ship activity just south and northwest of Pearl Harbor (Figure 3.0-13). Clear routes are seen to the east (to and from San Diego), west (to/from the Marianas Island Training and Testing area) and northwest (to/from Japan). For civilian shipping (Figure 3.0-11), cargo and bulk carrier traffic dominate much of the offshore areas. Fishing grounds were more toward the southwestern corner of the map area, and tugs appear to dominate inter-island traffic. The waters surrounding the Northwestern Hawaiian Islands (which are part of the protected Papahānaumokuākea Marine National Monument) are rarely traversed by Navy or civilian shipping, other than research vessels.

In Southern California, Mintz (2016) shows that geographic distribution of highest Navy surface ship activity around San Diego, is within roughly 50 NM of shore (Figure 3.0-14). Clear routes are seen to the west (to and from Pearl Harbor), and north along the coast (to/from the bases and operating areas in the Pacific Northwest). Civilian shipping distribution such as cargo and bulk carrier traffic dominates much of the offshore areas including routes to/from Japan and the Panama Canal or South America, while tankers are prominent closer in (Figure 3.0-12). There is also commercial ship traffic north and south between the Ports of Long Beach and Los Angeles, and the Panama Canal and South America. Tugs appear to be the most prominent traffic immediately next to the coast into and out of the ports. Passenger ships traverse Mexico's Pacific Coast along Baja California.

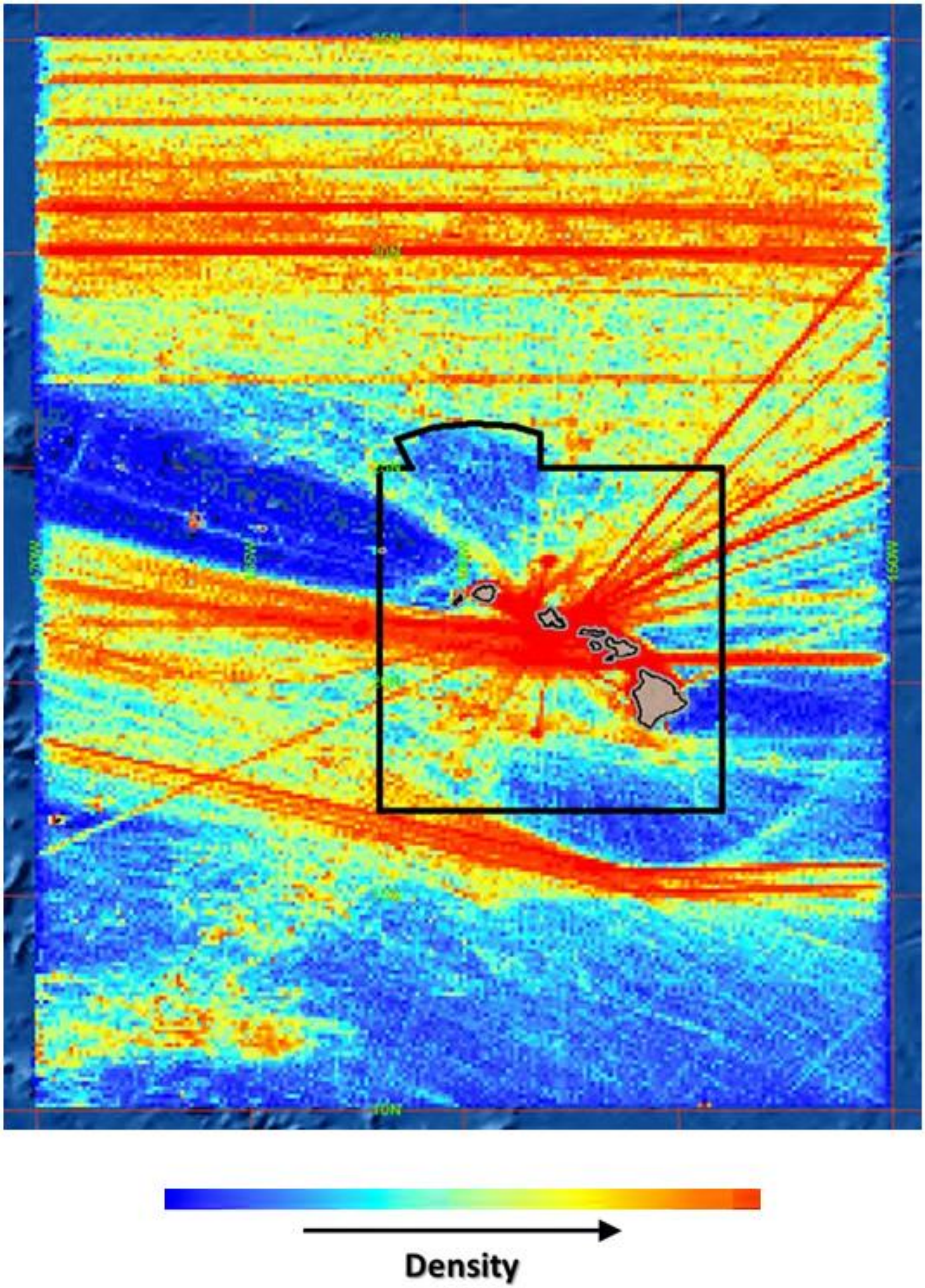

Figure 3.0-11: Relative Distribution of Commercial Vessel Traffic in the Hawaii Range Complex

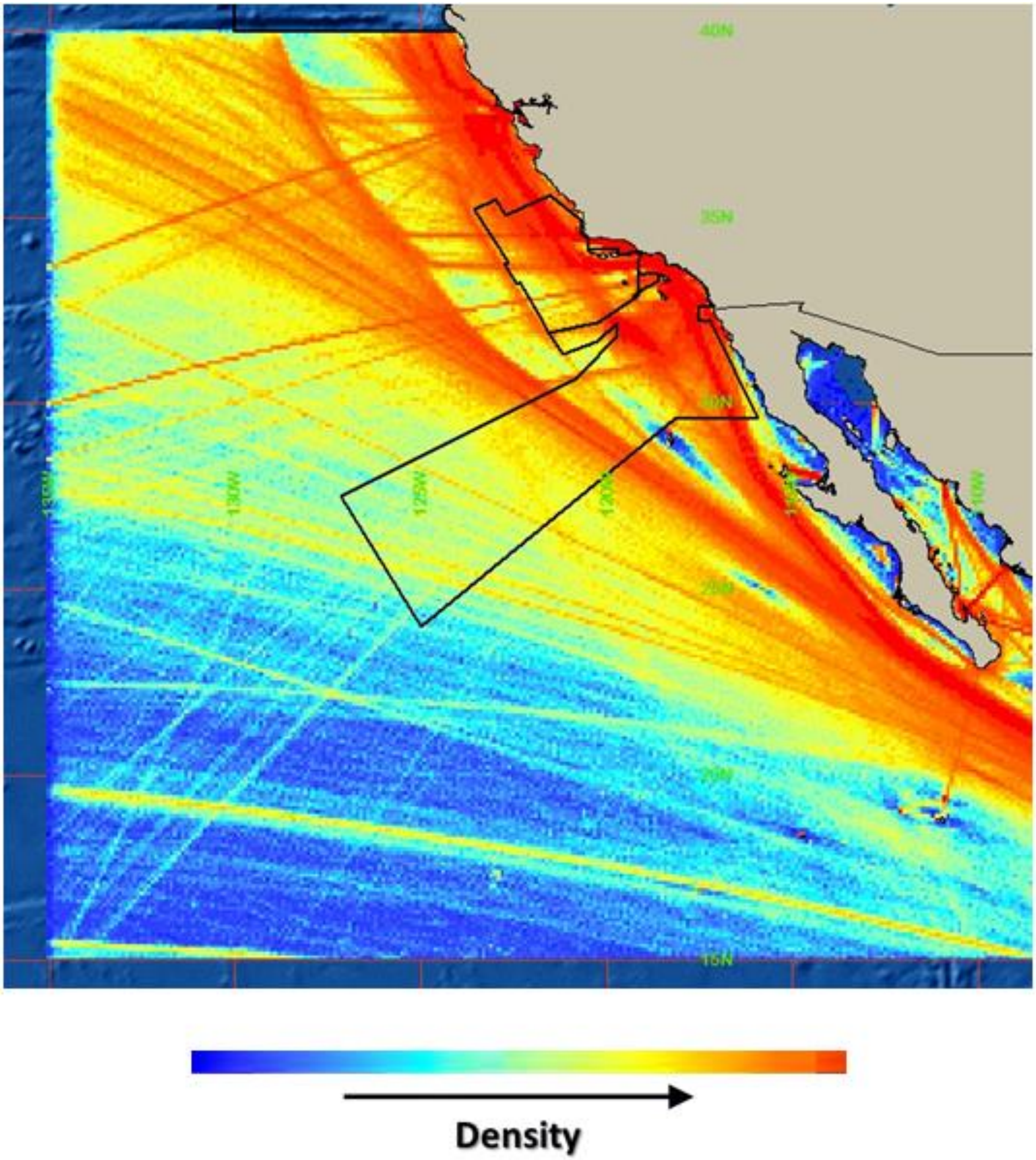

Figure 3.0-12: Relative Distribution of Commercial Vessel Traffic in the Southern California Portion of the Study Area

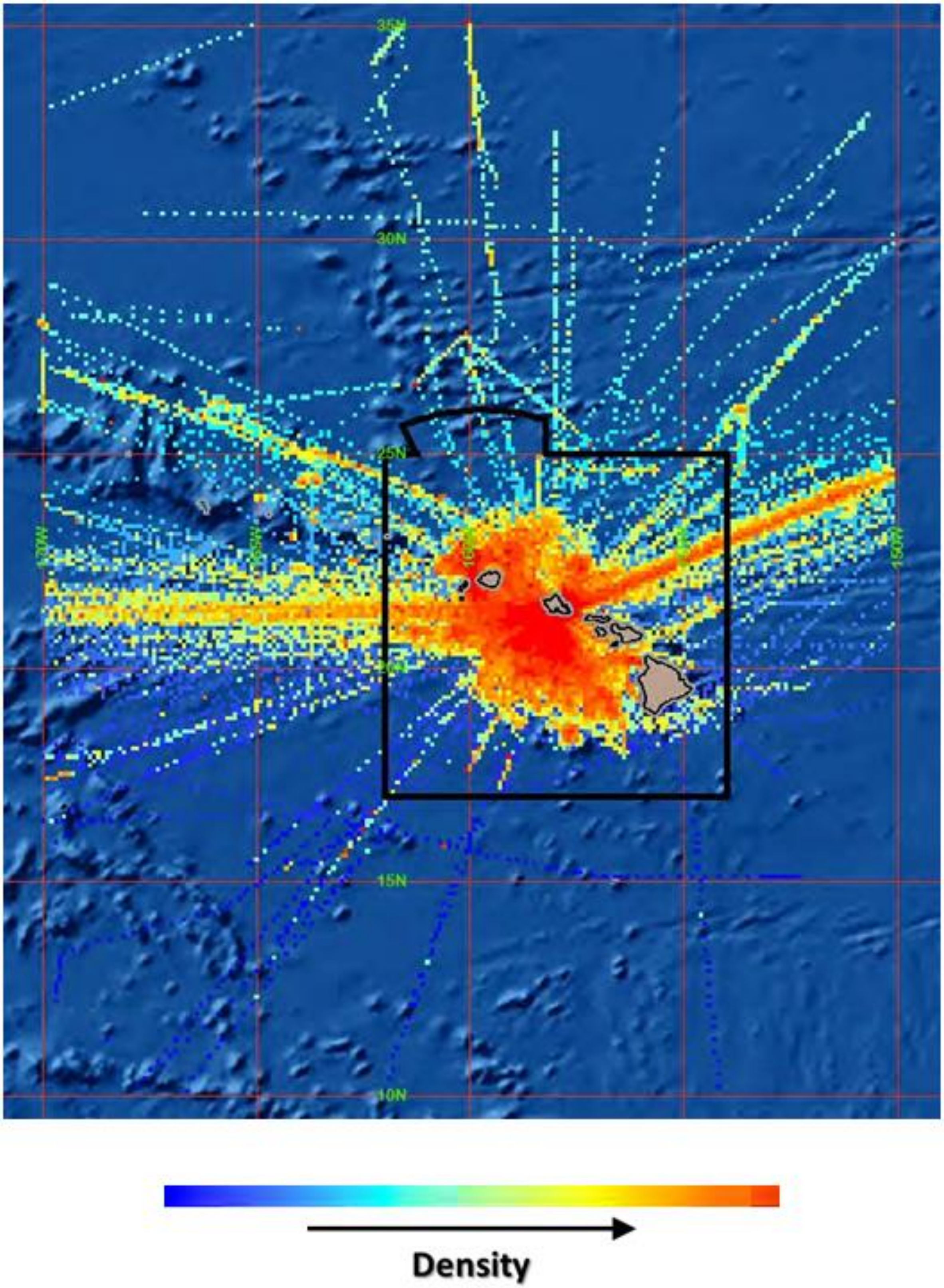

Figure 3.0-13: Relative Distribution of U.S. Navy Vessel Traffic in the Hawaii-Range Complex

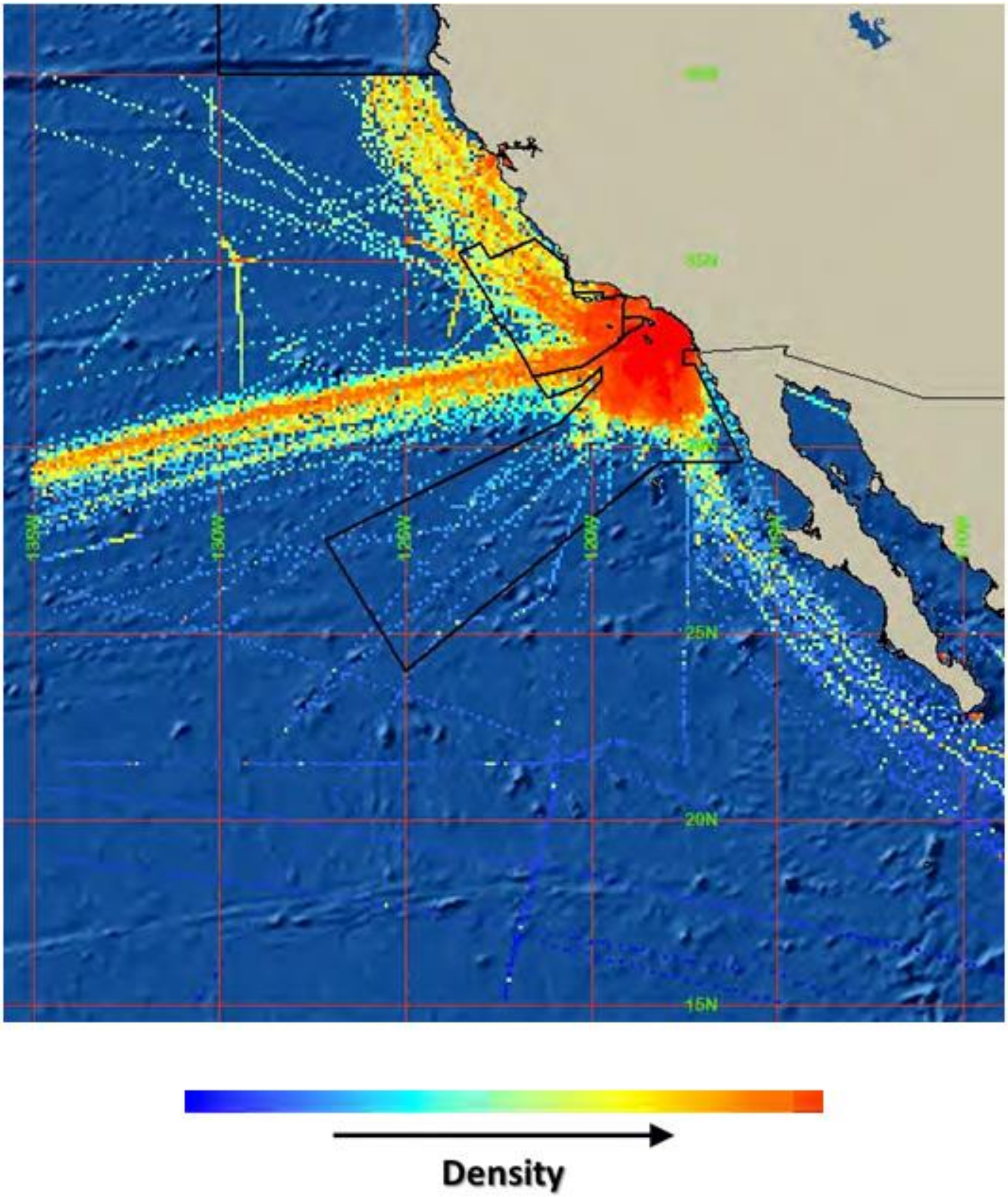

Figure 3.0-14: Relative Distribution of U.S. Navy Vessel Traffic in the Southern California Portion of the Study Area

3.0.3.3.1.5 Aircraft Noise

Fixed-wing, tiltrotor, and rotary-wing aircraft are used for a variety of training and testing activities throughout the Study Area, contributing both airborne and underwater sound to the ocean environment. Sounds in air are often measured using A-weighting, which adjusts received sound levels based on human hearing abilities (see Appendix D, Acoustic and Explosive Concepts). Aircraft used in training and testing generally have turboprop, or jet engines. Motors, propellers, and rotors produce the most noise, with some noise contributed by aerodynamic turbulence. Aircraft sounds have more energy at lower frequencies. Aircraft may transit to or from vessels at sea throughout the Study Area from established airfields on land. The majority of aircraft noise would be generated at air stations, which are outside the Study Area. Takeoffs and landings occur at established airfields as well as on vessels across the Study Area. Takeoffs and landings from Navy vessels produce in-water noise at a given location for a brief period as the aircraft climbs to cruising altitude. Military activities involving aircraft generally are dispersed over large expanses of open ocean but can be highly concentrated in time and location. Table 3.0-8 provides source levels for some typical aircraft used during training and testing in the Study Area and depicts comparable airborne source levels for the F-35A, EA-18G, and F/A-18C/D during takeoff.

Table 3.0-8: Representative Aircraft Sound Characteristics

Noise Source	*Sound Pressure Level*
In-Water Noise Level	
F/A-18 Subsonic at 1,000 ft. (300 m) Altitude	152 dB re 1 µPa at 2 m below water surface[1]
F/A-18 Subsonic at 10,000 ft. (3,000 m) Altitude	128 dB re 1 µPa at 2 m below water surface[1]
H-60 Helicopter Hovering at 82 ft. (25 m) Altitude	Approximately 125 dB re 1 µPa at 1 m below water surface[2*]
Airborne Noise Level	
F/A-18C/D Under Military Power	143 dBA re 20 µPa at 13 m from source[3]
F/A-18C/D Under Afterburner	146 dBA re 20 µPa at 13 m from source[3]
F35-A Under Military Power	145 dBA re 20 µPa at 13 m from source[3]
F-35-A Under Afterburner	148 dBA re 20 µPa at 13 m from source[3]
H-60 Helicopter Hovering at 82 ft. (25 m) Altitude	113 dBA re 20 µPa at 25 m from source[2]
H-60 Helicopter Hovering at 82 ft. (25 m) Altitude	113 dBA re 20 µPa at 25 m from source[2]
F-35A Takeoff Through 1,000 ft. (300 m) Altitude	119 dBA re 20 $\mu Pa^2 s$[4**] (per second of duration)
EA-18G Takeoff Through 1,622 ft. (500 m) Altitude	115 dBA re 20 $\mu Pa^2 s$[5**] (per second of duration)

Sources: [1]Eller and Cavanagh (2000) [2]Bousman and Kufeld (2005); [3]U.S. Naval Research Advisory Committee (2009), [4]U.S. Department of the Air Force (2016), [5]U.S. Department of the Navy (2012a)
* estimate based on in-air level
**average sound exposure level
Notes: dB re 1 µPa = decibel(s) referenced to 1 micropascal, dBA re 20 µPa = A-weighted decibel(s) referenced to 20 micropascals, m = meter(s), ft. = feet

Underwater Transmission of Aircraft Noise

Sound generated in air is transmitted to water primarily in a narrow area directly below the source (Appendix D, Acoustic and Explosive Concepts). A sound wave propagating from any source must enter the water at an angle of incidence of about 13° or less from the vertical for the wave to continue propagating under the water's surface. At greater angles of incidence, the water surface acts as an effective reflector of the sound wave and allows very little penetration of the wave below the water (Urick, 1983). Water depth and bottom conditions strongly influence how the sound from airborne sources propagates underwater. At lower altitudes, sound levels reaching the water surface would be higher, but the transmission area would be smaller. As the sound source gains altitude, sound reaching the water surface diminishes, but the possible transmission area increases. Estimates of underwater sound pressure level are provided for representative aircraft in Table 3.0-8.

Noise generated by fixed-wing aircraft is transient in nature and extremely variable in intensity. Most fixed-wing aircraft sorties (a flight mission made by an individual aircraft) would occur above 3,000 ft. Air combat maneuver altitudes generally range from 5,000 to 30,000 ft. above ground level, and typical airspeeds range from very low (less than 200 knots) to high subsonic (less than 600 knots). Sound exposure levels at the sea surface from most air combat maneuver overflights are expected to be less than 85 A-weighted decibels (based on an F/A-18 aircraft flying at an altitude of 5,000 ft. above ground level and at a subsonic airspeed [400 knots] (U.S. Department of the Navy, 2016a)). Exposure to fixed-wing aircraft noise would be brief (seconds) as an aircraft quickly passes overhead.

Helicopters

Noise generated from helicopters is transient in nature and extremely variable in intensity. In general, helicopters produce lower frequency sounds and vibration at a higher intensity than fixed-wing aircraft (Richardson et al., 1995). Helicopter sounds contain dominant tones from the rotors that are generally below 500 Hz. Helicopters often radiate more sound forward than backward. The underwater noise produced is generally brief when compared with the duration of audibility in the air and is estimated to be 125 dB re 1 µPa at 1 m below water surface for a UH-60 hovering 82 ft. (25 m) altitude (Bousman & Kufeld, 2005).

Helicopter unit level training typically entails single-aircraft sorties over water that start and end at an air station, although flights may occur from ships at sea. Individual flights typically last about two to four hours. Some events require low-altitude flights over a defined area, such as mine countermeasure activities deploying towed systems. Most helicopter sorties associated with mine countermeasures would occur at altitudes as low as 75-100 ft. Likewise, in some anti-submarine warfare events, a dipping sonar is deployed from a line suspended from a helicopter hovering at low altitudes over the water.

Sonic Booms

An intense but infrequent type of aircraft noise is the sonic boom, produced when an aircraft exceeds the speed of sound. Supersonic aircraft flights are not intentionally generated below 30,000 ft. unless over water and more than 30 NM from inhabited coastal areas or islands. Although deviation from these guidelines may be authorized for tactical missions that require supersonic flight, phases of formal training requiring supersonic speeds, research and test flights that require supersonic speeds, and for flight demonstration purposes when authorized by the Chief of Naval Operations (U.S. Department of the Navy, 2016a).

Several factors that influence sonic booms include weight, size, and shape of aircraft or vehicle; altitude; flight paths; and atmospheric conditions. A larger and heavier aircraft must displace more air and create more lift to sustain flight, compared with small, light aircraft. Therefore, larger aircraft create sonic booms that are stronger than those of smaller, lighter aircraft. Consequently, the larger and heavier the aircraft, the stronger the shock waves (U.S. Department of the Navy & Department of Defense, 2007). Aircraft maneuvers that result in changes to acceleration, flight path angle, or heading can also affect the strength of a boom. In general, an increase in flight path angle (lifting the aircraft's nose) will diffuse a boom while a decrease (lowering the aircraft's nose) will focus it. In addition, acceleration will focus a boom while deceleration will weaken it. Any change in horizontal direction will focus a boom, causing two or more wave fronts that originated from the aircraft at different times to coincide exactly (U.S. Department of the Navy, 2001). Atmospheric conditions such as wind speed and direction and air temperature and pressure can also influence the sound propagation of a sonic boom.

Of all the factors influencing sonic booms, increasing altitude is the most effective method of reducing sonic boom intensity. The width of the boom "carpet" or area exposed to sonic boom beneath an aircraft is about 1 mi. for each 1,000 ft. of altitude. For example, an aircraft flying supersonic, straight and level at 50,000 ft. can produce a sonic boom carpet about 50 mi. wide. The sonic boom, however, would not be uniform, and its intensity at the water surface would decrease with greater aircraft altitude. Maximum intensity is directly beneath the aircraft and decreases as the lateral distance from the flight path increases until shock waves refract away from the ground or water surface and the sonic boom attenuates. The lateral spreading of the sonic boom depends only on altitude, speed, and the atmosphere and is independent of the vehicle's shape, size, and weight. The ratio of the aircraft length to maximum cross-sectional area also influences the intensity of the sonic boom. The longer and more slender the aircraft, the weaker the shock waves. The wider and more blunt the aircraft, the stronger the shock waves can be (U.S. Department of the Navy & Department of Defense, 2007).

In air, the energy from a sonic boom is concentrated in the frequency range from 0.1 to 100 Hz. The underwater sound field due to transmitted sonic boom waveforms is primarily composed of low-frequency components (Sparrow, 2002), and frequencies greater than 20 Hz have been found to be difficult to observe at depths greater than 33 ft. (10 m) (Sohn et al., 2000). F/A-18 Hornet supersonic flight was modeled to obtain peak SPLs and energy flux density at the water surface and at depth (U.S. Department of the Air Force, 2000). These results are shown in Table 3.0-9.

Table 3.0-9: Sonic Boom Underwater Sound Levels Modeled for F/A-18 Hornet Supersonic Flight

*Mach Number**	*Aircraft Altitude (km)*	*Peak SPL (dB re 1 µPa)*			*Energy Flux Density (dB re 1 µPa^2-s)*[1]		
		At surface	*50 m Depth*	*100 m Depth*	*At surface*	*50 m Depth*	*100 m Depth*
1.2	1	176	138	126	160	131	122
	5	164	132	121	150	126	117
	10	158	130	119	144	124	115
2	1	178	146	134	161	137	128
	5	166	139	128	150	131	122
	10	159	135	124	144	127	119

* Mach number equals aircraft speed divided by the speed of sound.
Notes: SPL = sound pressure level, dB re 1 µPa = decibel(s) referenced to 1 micropascal, dB re 1 µPa^2-s = decibel(s) referenced to 1 micropascal squared seconds, m = meter(s)
[1] Equivalent to SEL for a plane wave.

3.0.3.3.1.6 Weapon Noise

The Navy trains and tests using a variety of weapons, as described in Appendix A (Navy Activity Descriptions). Depending on the weapon, incidental (unintentional) noise may be produced at launch or firing, while in flight, or upon impact. Other devices intentionally produce noise to serve as a non-lethal deterrent. Not all weapons utilize explosives, either by design or because they are non-explosive practice munitions. Noise produced by explosives, both in air and water, are discussed in Section 3.0.3.3.2 (Explosive Stressors).

Noise associated with large-caliber weapons firing and the impact of non-explosive practice munitions or kinetic weapons would typically occur at locations greater than 12 NM from shore in warning areas or special use airspace for safety reasons, with the exception of areas near San Clemente Island in the Southern California Range Complex and near Kaula Island and the Pacific Missile Range Facility in the Hawaii Range Complex. Small- and medium-caliber weapons firing could occur throughout the Study Area in identified training areas.

Examples of some types of weapons noise are shown in Table 3.0-10. Examples of launch noise are provided in the table. Noise produced by other weapons and devices are described further below.

Table 3.0-10: Example Weapons Noise

Noise Source	*Sound Level*
In-Water Noise Level	
Naval Gunfire Muzzle Blast (5-inch)	Approximately 200 dB re 1 µPa peak directly under gun muzzle at 1.5 m below the water surface[1]
Airborne Noise Level	
Naval Gunfire Muzzle Blast (5-inch)	178 dB re 20 µPa peak directly below the gun muzzle above the water surface[1]
Hellfire Missile Launch from Aircraft	149 dB re 20 µPa at 4.5 m[2]
Advanced Gun System Missile (115-millimeter)	133-143 dBA re 20 µPa between 12 and 22 m from the launcher on shore[3]
RIM 116 Surface-to-Air Missile	122-135 dBA re 20 µPa between 2 and 4 m from the launcher on shore[3]
Tactical Tomahawk Cruise Missile	92 dBA re 20 µPa 529 m from the launcher on shore[3]

Sources: [1]Yagla and Stiegler (2003); [2]U.S. Department of the Army (1999); [3]U.S. Department of the Navy (2013)
Notes: dB re 1 µPa = decibel(s) referenced to 1 micropascal, dB re 20 µPa = decibel(s) referenced to 20 micropascals, dBA re 20 µPa = A-weighted decibel(s) referenced to 20 micropascals, m = meter(s)

Muzzle Blast from Naval Gunfire

Firing a gun produces a muzzle blast in air that propagates away from the gun with strongest directivity in the direction of fire (Figure 3.0-15). Because the muzzle blast is generated at the gun, the noise decays with distance from the gun. The muzzle blast has been measured for the largest gun analyzed in the EIS/OEIS, the 5-inch (in.) large-caliber naval gun. At a distance of 3,700 ft. from the gun, which was fired at 10° elevation angle, and at 10° off the firing line, the in-air received level was 124 dB re 20 µPa SPL peak for the atmospheric conditions of the test (U.S. Department of the Navy, 1981). Measurements were obtained for additional distances and angles off the firing line, but were specific to the atmospheric conditions present during the testing.

As the pressure from the muzzle blast from a ship-mounted large-caliber gun propagates in air toward the water surface, the pressure can be both reflected from the water surface and transmitted into the water. As explained in Appendix D (Acoustic and Explosive Concepts), most sound enters the water in a narrow cone beneath the sound source (within about 13–14° of vertical), with most sound outside of this cone being totally reflected from the water surface. In-water sound levels were measured during the muzzle blast of a 5 in. large-caliber naval gun. The highest possible sound level in the water (average peak SPL of 200 dB re 1 µPa, measured 5 ft. below the surface) was obtained when the gun was fired at the lowest angle, placing the blast closest to the water surface (Yagla & Stiegler, 2003). The unweighted sound exposure level would be expected to be 15–20 dB lower than the peak pressure, making the highest possible sound exposure level in the water about 180 to 185 dB re 1 μPa^2-s directly below the muzzle blast. Other gunfire arrangements, such as with smaller caliber weapons or greater angles of fire, would result in less sound entering the water. The sound entering the water would have the strongest directivity directly downward beneath the gun blast, with lower sound pressures at increasing angles of incidence until the angle of incidence is reached where no sound enters the water.

Source: Yagla & Stiegler (2003)

Figure 3.0-15: Gun Blast and Projectile from a 5"/54 Navy Gun

Large-caliber gunfire also sends energy through the ship structure and into the water. This effect was investigated in conjunction with the measurement of 5 in. gun firing described above. The energy transmitted through the ship to the water for a typical round was about 6 percent of that from the muzzle blast impinging on the water (U.S. Department of the Navy, 2000). Therefore, sound transmitted from the gun through the hull into the water is a minimal component of overall weapons firing noise.

Supersonic Projectile Bow Shock Wave

Supersonic projectiles, such as a fired gun shell or kinetic energy weapon, create a bow shock wave along the line of fire. A bow shock wave is an impulsive sound caused by a projectile exceeding the speed of sound [for more explanation, see Appendix D (Acoustic and Explosive Concepts)]. The bow shock wave itself travels at the speed of sound in air. The projectile bow shock wave created in air by a shell in flight at supersonic speeds propagates in a cone (generally about 65°) behind the projectile in the direction of fire (U.S. Department of the Navy, 1981). Exposure to the bow shock wave is very brief.

Projectiles from a 5 in./ 54 caliber gun would travel at approximately 2,600 ft./second, and the associated bow shock wave is subjectively described as a “crack” noise (U.S. Department of the Navy, 1981). Measurements of a 5 in. projectile shock wave ranged from 140 to 147 dB re 20 µPa SPL peak taken at the ground surface at 0.59 NM distance from the firing location and 10° off the line of fire for safety (approximately 190 m from the shell’s trajectory) (U.S. Department of the Navy, 1981).

Hyperkinetic projectiles may travel up to and exceed approximately six times the speed of sound in air, or about 6,500 ft./second (2014). For a hyperkinetic projectile sized similar to the 5 in. shell, peak pressures would be expected to be several dB higher than those described for the 5 in. projectile above, following the model in U.S. Department of the Navy (1981).

Like sound from the gun muzzle blast, sound waves from a projectile in flight could only enter the water in a narrow cone beneath the sound source, with in-air sound being totally reflected from the water surface outside of the cone. The region of underwater sound influence from a single traveling shell would be relatively narrow and the duration of sound influence would be brief at any location.

Launch Noise

Missiles can be rocket or jet propelled and launches typically occur far offshore in special use airspace such as warning areas, air traffic control assigned airspace, and restricted areas. Sound due to missile and target launches is typically at a maximum at initiation of the booster rocket. It rapidly fades as the missile or target reaches optimal thrust conditions and the missile or target reaches a downrange distance where the booster burns out and the sustainer engine continues. Examples of launch noise sound levels are shown in Table 3.0-10.

Impact Noise (Non-Explosive)

Any object dropped in the water would create a noise upon impact, depending on the object's size, mass, and speed. Sounds of this type are produced by the kinetic energy transfer of the object with the target surface and are highly localized to the area of disturbance. A significant portion of an object's kinetic energy would be lost to splash, any deformation of the object, and other forms of non-mechanical energy (McLennan, 1997). The remaining energy could contribute to sound generation. Most objects would be only momentarily detectable, if at all, but some large objects traveling at high speeds could generate a broadband impulsive sound upon impact with the water surface. Sound associated with impact events is typically of low frequency (less than 250 Hz) and of short duration.

Long Range Acoustic Device

The Long Range Acoustic Device is a communication device that can be used to warn vessels against continuing towards a high value asset by emitting loud sounds in air. Although not a weapon, the Long Range Acoustic Device (and other hailing and deterrent devices) is considered along with in-air sounds produced by Navy sources. The system would typically be used in training activities nearshore, and use would be intermittent during these activities. Source levels at 1 m range between 137 A-weighted decibels (dBA) re 1 µPa for small portable systems and 153 dBA re 1 µPa for large systems. Sound would be directed within a 30–60° wide zone and would be directed over open water.

3.0.3.3.2 Explosive Stressors

This section describes the characteristics of explosions during naval training and testing. The activities analyzed in the EIS/OEIS that use explosives are described in Appendix A (Navy Activity Descriptions). This section provides the basis for analysis of explosive impacts on resources in the remainder of Chapter 3 (Affected Environment and Environmental Consequences). Explanations of the terminology and metrics used when describing explosives in this EIS/OEIS are in Appendix D (Acoustic and Explosive Concepts).

The near-instantaneous rise from ambient to an extremely high peak pressure is what makes an explosive shock wave potentially damaging. Farther from an explosive, the peak pressures decay and the explosive waves propagate as an impulsive, broadband sound. Several parameters influence the effect of an explosive: the weight of the explosive warhead, the type of explosive material, the boundaries and characteristics of the propagation medium, and, in water, the detonation depth. The net explosive weight, the explosive power of a charge expressed as the equivalent weight of trinitrotoluene (TNT), accounts for the first two parameters. The effects of these factors are explained in Appendix D (Acoustic and Explosive Concepts).

3.0.3.3.2.1 Explosions in Water

Explosive detonations during training and testing activities are associated with high-explosive munitions, including, but not limited to, bombs, missiles, rockets, naval gun shells, torpedoes, mines, demolition charges, and explosive sonobuoys. Explosive detonations during training and testing involving the use of high-explosive munitions, including bombs, missiles, and naval gun shells, could occur in the air or near the water's surface. Explosive detonations associated with torpedoes and explosive sonobuoys would occur in the water column; mines and demolition charges could be detonated in the water column or on the ocean bottom. Most detonations would occur in waters greater than 200 ft. in depth, and greater than 3 NM from shore, with exceptions for Mine Warfare ranges at Silver Strand Training Complex, San Clemente Island, and Puuloa Underwater Range proximate to Pearl Harbor. Section 5.3.3 (Explosive Stressors) outlines the procedural mitigation measures for explosive stressors to reduce potential impacts on biological resources.

In order to better organize and facilitate the analysis of Navy training and testing activities using explosives that could detonate in water or at the water surface, explosive classification bins were developed. The use of explosive classification bins provides the same benefits as described for acoustic source classification bins in Section 3.0.3.3.1 (Acoustic Stressors).

Explosives detonated in water are binned by net explosive weight. The bins of explosives that are proposed for use in the Study Area are shown in Table 3.0-11. This table shows the number of in-water explosive items that could be used in any year under each action alternative for training and testing activities. A range of annual bin use indicates that use of that bin is anticipated to vary annually, consistent with the variation in the number of annual events described in Chapter 2 (Description of Proposed Action and Alternatives). Over any 5-year period, both action alternatives take any annual variability into account.

In addition to the explosives quantitatively analyzed for impacts to protected species shown in Table 3.0-11, the Navy uses some very small impulsive sources (less than 0.1 pound [lb.] net explosive weight), categorized in bin E0, that are not anticipated to result in takes of protected species. Quantitative modeling in multiple locations has validated that these sources have a very small zone of influence. These E0 charges, therefore, are categorized as *de minimis* sources and are qualitatively analyzed to determine the appropriate effects conclusions under NEPA in the appropriate resource impact analyses, as well as under the MMPA and the ESA.

Propagation of explosive pressure waves in water is highly dependent on environmental characteristics such as bathymetry, bottom type, water depth, temperature, and salinity, which affect how the pressure waves are reflected, refracted, or scattered; the potential for reverberation; and interference due to multi-path propagation. In addition, absorption greatly affects the distance over which higher frequency components of explosive broadband noise can propagate. Appendix D (Acoustic and Explosive Concepts) explains the characteristics of explosive detonations and how the above factors affect the propagation of explosive energy in the water. Because of the complexity of analyzing sound propagation in the ocean environment, the Navy relies on acoustic models in its environmental analyses that consider sound source characteristics and varying ocean conditions across the Study Area.

Table 3.0-11: Explosive Sources Quantitatively Analyzed that Could Be Used Underwater or at the Water Surface

Bin	Net Explosive Weight[1] (lb.)	Example Explosive Source	Training				Testing			
			Alternative 1		Alternative 2		Alternative 1		Alternative 2	
			Annual[2]	5-year Total	Annual[2]	5-year Total	Annual[2]	5-year Total	Annual[2]	5-year Total
E1	0.1–0.25	Medium-caliber projectiles	2,940	14,700	2,940	14,700	8,916–15,216	62,880	14,916–15,216	74,880
E2	> 0.25–0.5	Medium-caliber projectiles	1,746	8,730	1,746	8,730	0	0	0	0
E3	> 0.5–2.5	Large-caliber projectiles	2,797	13,985	2,797	13,985	2,880–3,124	14,844	3,124	15,620
E4	> 2.5–5	Mine neutralization charge	38	190	38	190	634–674	3,065	680	3,255
E5	> 5–10	5 in. projectile	4,730–4,830	23,750	4,830	24,150	1,400	7,000	1,400	7,000
E6	> 10–20	Hellfire missile	592	2,872	592	2,872	26–38	166	38	190
E7	> 20–60	Demo block/shaped charge	13	65	13	65	0	0	0	0
E8	> 60–100	Lightweight torpedo	33–38	170	38	190	57	285	57	285
E9	> 100–250	500 lb. bomb	410–450	2,090	450	2,250	4	20	4	20
E10	> 250–500	Harpoon missile	219–224	1,100	224	1,120	30	150	30	150
E11	> 500–650	650 lb. mine	7–17	45	17	85	12	60	18	90
E12	> 650–1,000	2,000 lb. bomb	16–21	77	21	97	0	0	0	0
E13	> 1,000–1,740	Multiple Mat Weave charges	9	45	9	45	0	0	0	0

[1] Net Explosive Weight refers to the equivalent amount of trinitrotoluene (TNT); the actual weight of a munition may be larger due to other components.
[2] Expected annual use may vary per bin because the number of events may vary from year to year, as described in Chapter 2 (Description of Proposed Action and Alternatives).
[3] E13 is not modeled for protected species impacts in water because most energy is lost into the air or to the bottom substrate due to detonation in very shallow water.

3.0.3.3.2.2 Explosions in Air

Explosions in air include detonations of projectiles and missiles during surface-to-air gunnery and air-to-air missile exercises conducted during air warfare. These explosions typically occur far above the water surface in special use airspace. Some typical types of explosive munitions that would be detonated in air during Navy activities are shown in Table 3.0-12. Various missiles, rockets, and medium and large-caliber projectiles may be explosive or non-explosive, depending on the objective of the training or testing activity in which they are used. Quantities of explosive and non-explosive missiles, rockets, and projectiles proposed for use during Navy training and testing are provided in Appendix F (Military Expended Materials and Direct Strike Impact Analyses).

Table 3.0-12: Typical Air Explosive Munitions During Navy Activities

Weapon Type[1]	*Net Explosive Weight (lb.)*	*Typical Altitude of Detonation (ft.)*
Surface-to-Air Missile		
RIM-66 SM-2 Standard Missile	80	> 15,000
RIM-116 Rolling Airframe Missile	39	< 3,000
RIM-7 Sea Sparrow	36	> 15,000 (can be used on low targets)
FIM-92 Stinger	7	< 3,000
Air-to-Air Missile		
AIM-9 Sidewinder	38	> 15,000
AIM-7 Sparrow	36	> 15,000
AIM-120 AMRAAM	17	> 15,000
Air-to-Surface Missile		
AGM-88 HARM	45	< 100
Projectile – Large- Caliber[2]		
5"/54 caliber HE-ET	7	< 100
5"/54 caliber Other	8	< 3,000

[1] Mission Design Series and popular name shown for missiles.
[2] Most medium and large-caliber projectiles used during Navy training and testing activities do not contain high explosives.
Notes: AMRAAM = Advanced Medium-Range Air-to-Air Missile, HARM = High-Speed Anti-Radiation Missile, HE-ET = High Explosive-Electronic Time

Bombs and projectiles that detonate at or near the water surface, which are considered for underwater impacts (see Table 3.0-11), would also release some explosive energy into the air. Appendix A (Navy Activity Descriptions) describes where activities with these stressors typically occur.

The explosive energy released by detonations in air has been well-studied (see Appendix D, Acoustic and Explosive Concepts) and basic methods are available to estimate the explosive energy exposure with distance from the detonation [e.g., (U.S. Department of the Navy, 1975)]. In air, the propagation of impulsive noise from an explosion is highly influenced by atmospheric conditions, including temperature and wind. While basic estimation methods do not consider the unique environmental conditions that may be present on a given day, they allow for approximation of explosive energy propagation under neutral atmospheric conditions. Explosions that occur during air warfare would typically be at a sufficient altitude that a large portion of the sound refracts upward due to cooling temperatures with increased altitude.

Missiles, rockets, projectiles, and other cased weapons will produce casing fragments upon detonation. These fragments may be of variable size and are ejected at supersonic speed from the detonation. The casing fragments will be ejected at velocities much greater than debris from any target due to the proximity of the casing to the explosive material. Unlike detonations on land targets, in-air detonations during Navy training and testing would not result in other propelled materials such as crater debris.

3.0.3.3.3 Energy Stressors

This section describes the characteristics of energy introduced through naval training and testing activities and the relative magnitude and location of these activities to provide the basis for analysis of potential impacts on resources from in-water electromagnetic devices, in-air electromagnetic devices, and lasers.

3.0.3.3.3.1 In-Water Electromagnetic Devices

Electromagnetic energy emitted into the water from magnetic influence mine neutralization systems is considered in this document. Table 3.0-13 shows the number and location of proposed activities, primarily mine sweeping, that include the use of in-water electromagnetic devices.

Table 3.0-13: Events Including In-Water Electromagnetic Devices

Activity Area	*Maximum Annual # of Events*		*5-Year # of Events*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Training				
SOCAL	340	340	1,700	1,700
Total	**340**	**340**	**1,700**	**1,700**
Testing				
HRC	10	10	48	48
SOCAL	86	86	428	428
Total	**96**	**96**	**476**	**476**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

In-water electromagnetic energy devices include towed or unmanned mine warfare systems that simply mimic the electromagnetic signature of a vessel passing through the water. None of the devices include any type of electromagnetic "pulse." A mine neutralization device could be towed through the water by a surface vessel or remotely operated vehicle, emitting an electromagnetic field and mechanically generated underwater sound to simulate the presence of a ship. The sound and electromagnetic signature cause nearby mines to detonate.

Generally, voltage used to power these systems is around 30 volts. Since saltwater is an excellent conductor, just 35 volts (capped at 55 volts) is required to generate the current. These are considered safe levels for marine species due to the low electric charge relative to salt water.

The static magnetic field generated by the mine neutralization devices is of relatively minute strength. Typically, the maximum magnetic field generated would be approximately 2,300 microteslas[1]. This level of electromagnetic density is very low compared to magnetic fields generated by other everyday items. The magnetic field generated is between the levels of a refrigerator magnet (15,000–20,000 microteslas) and a standard household can opener (up to 400 microteslas at 4 in.). The strength of the

[1] The microtesla is a unit of measurement of magnetic flux density, or "magnetic induction."

electromagnetic field decreases quickly away from the cable. The magnetic field generated is very weak, comparable to the earth's natural field (U.S. Department of the Navy, 2005).

The kinetic energy weapon (commonly referred to as the rail gun) will be tested and eventually used in training events aboard surface vessels, firing non-explosive projectiles at land- or sea-based targets. The system uses stored electrical energy to accelerate the projectiles, which are fired at supersonic speeds over great distances. The system charges for two minutes and fires in less than one second; therefore, the release of any electromagnetic energy would occur over a very short period. Also, the system is shielded so as not to affect shipboard controls and systems. The amount of electromagnetic energy released from this system is low and contained on the surface vessel. Therefore, this device is not expected to result in any electromagnetic impacts and will not be further analyzed for biological resources in this document.

3.0.3.3.3.2 In-Air Electromagnetic Devices

Sources of electromagnetic energy in the air include kinetic energy weapons, communications transmitters, radars, and electronic countermeasures transmitters. Electromagnetic devices on Navy platforms operate across a wide range of frequencies and power. On a single ship the source frequencies may range from 2 megahertz (MHz) to 14,500 MHz, and transmitter maximum average power may range from 0.25 watts to 1,280,00 watts.

The term radar was originally coined by the Navy to refer to Radio Detection And Ranging. A radar system is an electromagnetic device that emits radio waves to detect and locate objects. In most cases, basic radar systems operate by generating pulses of radio frequency energy and transmitting these pulses via directional antennae into space (Courbis & Timmel, 2008). Some of this energy is reflected by the target back to the antenna, and the signal is processed to provide useful information to the operator.

Radars come in a variety of sizes and power, ranging from wide-band milliwatt systems to very high-power systems that are used primarily for long-range search and surveillance (Courbis & Timmel, 2008). In general, radars operate at radio frequencies that range between 300 megahertz and 300 gigahertz, and are often classified according to their frequency range. Navy vessels commonly operate radar systems that include S-band and X-band electronically steered radar. S-band radar serves as the primary search and acquisition sensor capable of tracking and collecting data on a large number of objects while X-band radar can provide high resolution data on particular objects of interest and discrimination for weapons systems. Both systems employ a variety of waveforms and bandwidths to provide high-quality data collection and operational flexibility (Baird et al., 2016).

It is assumed that most Navy platforms associated with the Proposed Action will be transmitting from a variety of in-air electromagnetic devices at all times that they are underway, with very limited exceptions. Most of these transmissions (e.g., for routine surveillance, communications, and navigation) will be at low power. High-power settings are used for a small number of activities including ballistic missile defense training, missile and rocket testing, radar and other system testing, and signature analysis operations. The number of Navy vessels or aircraft in the Study Area at any given time varies and is dependent on local training or testing requirements. Therefore, in-air electromagnetic energy as part of the Proposed Action would be widely dispersed throughout the Study Area, but more concentrated in portions of the Study Area near ports, naval installations, and range complexes. Table 3.0-16 and Table 3.0-28 show the annual number and location of events involving vessels and aircraft, which provide a proxy for level of in-air electromagnetic device use for the purposes of this EIS/OEIS.

3.0.3.3.3.3 Lasers

The devices discussed here include lasers that can be organized into two categories: (1) low-energy lasers and (2) high-energy lasers. Low-energy lasers are used to illuminate or designate targets, to measure the distance to a target, to guide weapons, to aid in communication, and to detect or classify mines. High-energy lasers are used as weapons to create critical failures on air and surface targets.

Low-Energy Lasers

Within the category of low-energy lasers, the highest potential level of exposure would be from an underwater laser or an airborne laser beam directed at the ocean's surface. An assessment on the use of low-energy lasers by the Navy determined that low-energy lasers, including those involved in the training and testing activities in this EIS/OEIS, have an extremely low potential to impact marine biological resources (U.S. Department of the Navy, 2010). The assessment determined that the maximum potential for laser exposure is at the ocean's surface, where laser intensity is greatest (U.S. Department of the Navy, 2010). As the laser penetrates the water, 96 percent of a laser beam is absorbed, scattered, or otherwise lost (Ulrich, 2004). Based on the parameters of the low-energy lasers and the behavior and life history of major biological groups, it was determined the greatest potential for impact would be to the eye of a marine species. However, an animal's eye would have to be exposed to a direct laser beam for at least ten seconds or longer to sustain damage. U.S. Department of the Navy (2010) assessed the potential for damage based on species specific eye/vision parameters and the anticipated output from low-energy lasers, and determined that no animals were predicted to incur damage. Therefore, low-energy lasers are not further analyzed in this document for possible impacts to biological resources.

High-Energy Lasers

High-energy laser weapons testing involves the use of up to 30 kilowatts of directed energy as a weapon against small surface vessels and airborne targets. High-energy lasers would be employed from surface ships and are designed to create small but critical failures in potential targets. The high energy laser is expected to be used at short ranges. Table 3.0-14 shows the number and location of proposed testing events that include the use of high-energy lasers. Marine life at or near the ocean surface and birds could be susceptible to injury by high-energy lasers.

Table 3.0-14: Events Including High-Energy Lasers

Activity Area	*Maximum Annual # of Events*		*5-Year # of Events*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Testing				
HRC	100	100	498	498
SOCAL	324	324	1,394	1,394
Total	**424**	**424**	**1,892**	**1,892**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

3.0.3.3.4 Physical Disturbance and Strike Stressors

This section describes the characteristics of physical disturbance and strike stressors from Navy training and testing activities. It also describes the magnitude and location of these activities to provide the basis for analyzing the potential physical disturbance and strike impacts on resources in the remainder of Chapter 3 (Affected Environment and Environmental Consequences).

3.0.3.3.4.1 Vessels and In-Water Devices

Vessels

Vessels used as part of the Proposed Action include ships (e.g., aircraft carriers, surface combatants), support craft, and submarines ranging in size from 15 ft. to over 1,000 ft. Table 3.0-15 provides examples of the types of vessels, length, and speeds used in both testing and training activities. The U.S. Navy Fact Files, available on the Internet at http://www.navy.mil/navydata/fact.asp, provide the latest information on the quantity and specifications of the vessels operated by the Navy.

Navy ships transit at speeds that are optimal for fuel conservation or to meet operational requirements. Large Navy ships (greater than 18 m in length) generally operate at average speeds of 10–15 knots, and submarines generally operate at speeds in the range of 8–13 knots. Small craft (for purposes of this discussion, less than 18 m in length), which are all support craft, have much more variable speeds (0–50+ knots, dependent on the mission). While these speeds are considered averages and representative of most events, some vessels need to operate outside of these parameters. For example, to produce the required relative wind speed over the flight deck, an aircraft carrier vessel group engaged in flight operations must adjust its speed through the water accordingly. Also, there are other instances such as launch and recovery of a small rigid hull inflatable boat; vessel boarding, search, and seizure training events; or retrieval of a target when vessels would be dead in the water or moving slowly ahead to maintain steerage. There are a few specific events, including high-speed tests of newly constructed vessels, where vessels would operate at higher speeds.

Table 3.0-15: Representative Vessel Types, Lengths, and Speeds

Type	*Example(s)*	*Length*	*Typical Operating Speed*
Aircraft Carrier	Aircraft Carrier (CVN)	>1,000 ft.	10–15 knots
Surface Combatant	Cruisers (CG), Destroyers (DDG), Littoral Combat Ships (LCS)	300–700 ft.	10–15 knots
Amphibious Warfare Ship	Amphibious Assault Ship (LHA, LHD), Amphibious Transport Dock (LPD), Dock Landing Ship (LSD)	300–900 ft.	10–15 knots
Combat Logistics Force Ships	Fast Combat Support Ship (T-AOE), Dry Cargo/Ammunition Ship (T-AKE), Fleet Replenishment Oilers (T-AO)	600–750 ft.	8–12 knots
Support Craft/Other	Amphibious Assault Vehicle (AAV); Combat Rubber Raiding Craft (CRRC); Landing Craft, Mechanized (LCM); Landing Craft, Utility (LCU); Submarine Tenders (AS); Yard Patrol Craft (YP)	15–140 ft.	0–20 knots
Support Craft/Other – Specialized High Speed	High Speed Ferry/Catamaran; Patrol Combatants (PC); Rigid Hull Inflatable Boat (RHIB); Expeditionary Fast Transport (EPF) ; Landing Craft, Air Cushion (LCAC)	33–320 ft.	0–50+ knots
Submarines	Fleet Ballistic Missile Submarines (SSBN), Attack Submarines (SSN), Guided Missile Submarines (SSGN)	300–600 ft.	8–13 knots

Notes: > indicates greater than

The number of Navy vessels in the Study Area at any given time varies and is dependent on local training or testing requirements. Most activities include either one or two vessels and may last from a few hours to two weeks. Vessel movement as part of the Proposed Action would be widely dispersed throughout the Study Area, but more concentrated in portions of the Study Area near ports, naval installations, and range complexes.

In an attempt to determine traffic patterns for Navy and non-Navy vessels, the Center for Naval Analysis (Mintz & Parker, 2006) conducted a review of historic data for commercial vessels, coastal shipping patterns, and Navy vessels. Commercial and non-Navy traffic, which included cargo vessels, bulk carriers, passenger vessels, and oil tankers (all over 20 m in length), was heaviest along the U.S. West Coast between San Diego and Seattle (Puget Sound) and between the Hawaiian Islands (Mintz & Parker, 2006). Well-defined International shipping lanes within the Study Area are also heavily traveled. Compared to coastal vessel activity, there was relatively little concentration of vessels in the other portions of the Study Area (Mintz & Parker, 2006). Navy traffic in the Study Area was heaviest offshore of the naval ports at San Diego and Pearl Harbor.

Data from 2009 were analyzed by Mintz (2012) and Mintz and Filadelfo (2011) indicated that within the HSTT Study Area, large Navy vessels accounted for less than 10 percent of the total large vessel traffic (from estimated vessel hours using positional data) in that area. In the Southern California Range Complex where Navy vessel activity is concentrated within the Exclusive Economic Zone, the Navy vessels accounted for 24 percent of the total large vessel traffic.

Table 3.0-16 shows the number and location of proposed events that include the use of vessels. Each activity included in Table 3.0-16 could involve one or more vessels. As described above in Section 3.0.3.3 (Identifying Stressors for Analysis), activities are not always conducted independently of each other, as there are instances where a training activity could occur on a vessel while another training activity or a testing activity is being conducted on the same vessel simultaneously. The location and hours of Navy vessel usage for training and testing activities are most dependent upon the locations of Navy ports, piers, and established at-sea testing and training areas. These areas have not appreciably changed in decades and are not expected to change in the foreseeable future.

Table 3.0-16: Number and Location of Events Including Vessels

Activity Area	*Maximum Annual # of Events*		*5-Year # of Events*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Training				
HRC	5,598	5,598	27,829	27,973
SOCAL	14,752	14,770	73,502	73,796
Transit Corridor	184	184	920	920
Total	**20,534**	**20,552**	**102,251**	**102,689**
Testing				
HRC	1,100	1,108	5,299	5,427
SOCAL	2,758	2,771	12,562	13,741
Transit Corridor	4	4	20	20
Total	**3,862**	**3,883**	**17,881**	**19,188**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

While these estimates provide the average distribution of vessels, actual locations and hours of Navy vessel usage are dependent upon requirements, deployment schedules, annual budgets, and other unpredictable factors. Consequently, vessel use can be highly variable. Multiple activities usually occur from the same vessel, so increases in the number of activities do not typically result in increases in vessel use or transit. The manner in which the Navy uses vessels to accomplish its training and testing activities is likely to remain consistent with the range of variability observed over the last decade. Consequently, the Navy is not proposing appreciable changes in the levels, frequency, or locations where vessels have been used over the last decade.

In-Water Devices

In-water devices as discussed in this analysis include unmanned vehicles, such as remotely operated vehicles, unmanned surface vehicles, unmanned underwater vehicles, motorized autonomous targets, and towed devices. These devices are self-propelled and unmanned or towed through the water from a variety of platforms, including helicopters, unmanned underwater vehicles, and surface ships. In-water devices are generally smaller than most Navy vessels, ranging from several inches to about 50 ft. See Table 3.0-17 for a range of in-water devices used. These devices can operate anywhere from the water surface to the benthic zone. Most devices do not have a realistic potential to strike living marine resources because they either move slowly through the water column (e.g., most unmanned underwater vehicles) or are closely monitored by observers manning the towing platform who ensure the towed in-water device does not run into objects in the water. Because of their size and potential operating speed, unmanned surface vehicles are the in-water devices that operate in a manner with the most potential to strike living marine resources. Table 3.0-18 shows the number and location of proposed events that include the use of in-water devices. For a list of activities by name that include the use of in-water devices, see Appendix B (Activity Stressor Matrices).

Table 3.0-17: Representative Types, Sizes, and Speeds of In-Water Devices

Type	*Example(s)*	*Length*	*Typical Operating Speed*
Towed Device	Minehunting Sonar Systems; Improved Surface Tow Target; Towed Sonar System; MK-103, MK-104 and MK-105 Minesweeping Systems; Organic Airborne and Surface Influence Sweep	< 33 ft.	10–40 knots
Unmanned Surface Vehicle	MK-33 Seaborne Power Target Drone Boat, QST-35A Seaborne Powered Target, Ship Deployable Seaborne Target, Small Waterplane Area Twin Hull, Unmanned Influence Sweep System	< 50 ft.	Variable, up to 50+ knots
Large Unmanned Surface Vehicle	Research and Development Surface Vessels, Patrol Boats	< 200 ft.	Typical 1–15 knots, sprint 25–50 knots
Unmanned Underwater Vehicle	Acoustic Mine Targeting System, Airborne Mine Neutralization System, AN/AQS Systems, Archerfish Common Neutralizer, Crawlers, CURV 21, Deep Drone 8000, Deep Submergence Rescue Vehicle, Gliders, Expendable Mobile Anti-Submarine Warfare Training Targets, Magnum Remotely Operated Vehicle, Manned Portables, MK 30 Anti-Submarine Warfare Targets, Remote Multi-Mission Vehicle, Remote Minehunting System, Large Displacement Unmanned Underwater Vehicle	< 60 ft.	1–15 knots
Torpedoes	Light-weight and Heavy-weight Torpedoes	< 33 ft.	20–30 knots

Table 3.0-18: Number and Location of Events Including In-Water Devices

Activity Area	Maximum Annual # of Events		5-Year # of Events	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Training				
HRC	2,870	2,982	14,245	14,895
SOCAL	9,093	9,322	45,073	46,310
Transit Corridor	77	77	385	385
Total	**12,040**	**12,381**	**59,703**	**61,590**
Testing				
HRC	881	883	4,245	4,334
SOCAL	2,250	2,252	10,091	11,197
Transit Corridor	10	10	50	50
Total	**3,141**	**3,145**	**14,386**	**15,581**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

3.0.3.3.4.2 Military Expended Materials

Military expended materials that may cause physical disturbance or strike include (1) all sizes of non-explosive practice munitions (Table 3.0-19 and Table 3.0-20); (2) fragments from high-explosive munitions (Table 3.0-21 and Table 3.0-22); (3) expendable targets (Table 3.0-23 and Table 3.0-24); and (4) expended materials other than munitions, such as sonobuoys or torpedo accessories (Table 3.0-25 and Table 3.0-26). See Appendix F (Military Expended Materials and Direct Strike Impact Analyses) for more information on the type and quantities of military expended materials proposed to be used.

For living marine resources in the water column, the discussion of military expended material strikes focuses on the potential of a strike at the surface of the water. The effect of materials settling on the bottom will be discussed as an alteration of the bottom substrate and associated organisms (e.g., invertebrates and vegetation).

Table 3.0-19: Number and Location of Non-Explosive Practice Munitions Expended During Training Activities

Activity Area	Maximum Annual # of Munitions		5-Year # of Munitions	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Torpedoes[1]				
HRC	426	426	2,130	2,130
SOCAL	398	398	1,414	1,414
Total	**824**	**824**	**3,544**	**3,544**
Bombs				
HRC	2,862	2,862	14,310	14,310
SOCAL	12	12	60	60
Transit Corridor	90	90	450	450
Total	**2,964**	**2,964**	**14,820**	**14,820**

Table 3.0-19: Number and Location of Non-Explosive Practice Munitions Expended During Training Activities (continued)

Activity Area	*Maximum Annual # of Munitions*		*5-Year # of Munitions*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Rockets				
SOCAL	2,584	2,584	12,920	12,920
Rockets (Flechette)				
SOCAL	129	129	645	645
Large Caliber Projectiles				
HRC	666	666	3,010	3,330
SOCAL	7,146	7,146	35,650	35,730
Transit Corridor	384	384	1,920	1,920
Total	**8,196**	**8,196**	**40,580**	**40,980**
Large Caliber – Casings Only				
SOCAL	4,950	4,950	24,750	24,750
Medium Caliber Projectiles[2]				
HRC	163,225	163,225	816,125	816,125
SOCAL	489,255	489,255	2,446,275	2,446,275
Transit Corridor	43,600	43,600	218,000	218,000
Total	**696,080**	**696,080**	**3,480,400**	**3,480,400**
Small Caliber Projectiles				
HRC	415,851	415,851	1,919,250	2,079,250
SOCAL	3,741,000	3,741,000	18,665,000	18,705,000
Transit Corridor	100,000	100,000	500,000	500,000
Total	**4,256,851**	**4,256,851**	**21,084,250**	**21,284,250**

[1]Non-explosive torpedoes are recovered after use.
[2] Medium Caliber Projectiles includes Anti-Swimmer Grenades.
Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

Table 3.0-20: Number and Location of Non-Explosive Practice Munitions Expended During Testing Activities

Activity Area	*Maximum Annual # of Munitions*		*5-Year # of Munitions*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Torpedoes[1]				
HRC	489	489	2,308	2,323
SOCAL	660	660	3,066	3,174
Total	**1,148**	**1,148**	**5,373**	**5,496**
Bombs				
HRC	56	56	280	280
SOCAL	114	114	570	570
Total	**170**	**170**	**850**	**850**

Table 3.0-20: Number and Location of Non-Explosive Practice Munitions Expended During Testing Activities (continued)

Activity Area	*Maximum Annual # of Munitions*		*5-Year # of Munitions*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Rockets				
HRC	7	7	34	34
SOCAL	97	97	400	484
Total	**104**	**104**	**434**	**518**
Rockets (Flechette)				
HRC	3	3	12	12
SOCAL	33	33	134	162
Total	**36**	**36**	**146**	**174**
Missiles				
HRC	278	278	1,390	1,390
SOCAL	796	796	3,940	3,964
Total	**1,074**	**1,074**	**5,330**	**5,354**
Large Caliber Projectiles				
HRC	21,704	21,704	108,520	108,520
SOCAL	21,854	21,854	109,270	109,270
Total	**43,558**	**43,558**	**217,790**	**217,790**
Kinetic Energy Rounds				
HRC	7,400	7,400	37,000	37,000
SOCAL	7,736	7,736	38,680	38,680
Total	**15,136**	**15,136**	**75,680**	**75,680**
Medium Caliber Projectiles[2]				
HRC	222,515	222,515	1,112,575	1,112,575
SOCAL	302,461	302,461	1,476,305	1,512,305
Total	**524,976**	**524,976**	**2,588,880**	**2,624,880**
Small Caliber Projectiles				
HRC	44,100	44,100	220,500	220,500
SOCAL	90,800	90,800	454,000	454,000
Total	**134,900**	**134,900**	**674,500**	**674,500**

[1]Non-explosive torpedoes are recovered after use.
[2]Medium Caliber Projectiles includes Anti-Swimmer Grenades.
Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

Table 3.0-21: Number and Location of Explosives that May Result in Fragments Used During Training Activities

Activity Area	*Maximum Annual # of Munitions*		*5-Year # of Munitions*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Torpedoes				
HRC	14	14	38	70
SOCAL	3	3	7	15
Total	**17**	**17**	**45**	**85**
Neutralizers				
HRC	6	6	30	30
SOCAL	32	32	160	160
Total	**38**	**38**	**190**	**190**
Bombs				
HRC	328	328	1,496	1,640
SOCAL	341	341	1,661	1,697
Total	**669**	**669**	**3,157**	**3,337**
Rockets				
HRC	627	627	3,135	3,135
SOCAL	570	570	2,850	2,850
Total	**1,197**	**1,197**	**5,985**	**5,985**
Missiles				
HRC	146	146	698	730
SOCAL	267	267	1,327	1,335
Total	**413**	**413**	**2,025**	**2,065**
Large Caliber Projectiles				
HRC	2,500	2,500	12,180	12,500
SOCAL	5,684	5,684	28,340	28,420
Transit Corridor	32	32	160	160
Total	**8,216**	**8,216**	**40,680**	**41,080**
Medium Caliber Projectiles[1]				
HRC	5,356	5,356	26,780	26,780
SOCAL	5,896	5,896	29,480	29,480
Transit Corridor	200	200	1,000	1,000
Total	**11,452**	**11,452**	**57,260**	**57,260**

[1] Medium Caliber Projectiles includes Anti-Swimmer Grenades.
Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

Table 3.0-22: Number and Location of Explosives that May Result in Fragments Used During Testing Activities

Activity Area	*Maximum Annual # of Munitions*		*5-Year # of Munitions*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Torpedoes				
HRC	34	34	170	170
SOCAL	34	34	170	170
Total	**68**	**68**	**340**	**340**
Sonobuoys				
SOCAL	72	72	360	360
Neutralizers				
HRC	144	144	576	576
SOCAL	434	440	2,009	2,199
Total	**578**	**584**	**2,585**	**2,775**
Bombs				
HRC	2	2	10	10
SOCAL	2	2	10	10
Total	**4**	**4**	**20**	**20**
Rockets				
HRC	3	3	15	15
SOCAL	203	203	815	1,015
Total	**206**	**206**	**830**	**1,030**
Missiles				
HRC	395	395	1,973	1,973
SOCAL	454	454	2,244	2,268
Total	**849**	**849**	**4,217**	**4,241**
Buoys				
HRC	567	567	2,835	2,835
SOCAL	617	617	3,085	3,085
Total	**1,184**	**1,184**	**5,920**	**5,920**
Anti-Torpedo Torpedo				
HRC	148	148	738	738
SOCAL	148	148	738	738
Total	**296**	**296**	**1,476**	**1,476**
Mines				
SOCAL	0	6	0	30
Large Caliber Projectiles				
HRC	4,684	4,684	23,418	23,418
SOCAL	4,744	4,744	23,718	23,718
Total	**9,428**	**9,428**	**47,136**	**47,136**

Table 3.0-22: Number and Location of Explosives that May Result in Fragments Used During Testing Activities (continued)

Activity Area	Maximum Annual # of Munitions		5-Year # of Munitions	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Medium Caliber Projectiles[1]				
HRC	15,365	15,365	76,825	76,825
SOCAL	27,341	27,341	122,705	134,705
Total	**42,706**	**42,706**	**199,530**	**211,530**

[1] Medium Caliber Projectiles includes Anti-Swimmer Grenades.
Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

Table 3.0-23: Number and Location of Targets Expended During Training Activities

Activity Area	Maximum Annual # of Targets		5-Year # of Targets	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Sub-surface Targets (Stationary)				
HRC	1	1	5	5
SOCAL	3	3	11	11
Total	**4**	**4**	**16**	**16**
Sub-surface Targets (Mobile)				
HRC	114	185	568	922
SOCAL	72	290	356	1,447
Transit Corridor	45	182	225	910
Total	**231**	**657**	**1,149**	**3,279**
Surface Targets (Stationary)				
HRC	312	484	1,560	2,419
SOCAL	605	669	3,024	3,341
Transit Corridor	43	77	213	381
Total	**960**	**1,230**	**4,797**	**6,141**
Surface Targets (Mobile)				
HRC	1,398	1,398	6,989	6,989
SOCAL	3,466	3,466	17,329	17,329
Transit Corridor	132	132	658	658
Total	**4,996**	**4,996**	**24,976**	**24,976**
Air Targets (Decoy)				
HRC	2,078	2,078	10,388	10,388
SOCAL	14	14	69	69
Transit Corridor	30	30	150	150
Total	**2,122**	**2,122**	**10,607**	**10,607**

Table 3.0-23: Number and Location of Targets Expended During Training Activities (continued)

Activity Area	Maximum Annual # of Targets		5-Year # of Targets	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Mine Shapes[1]				
HRC	13	13	64	64
SOCAL	83	83	415	415
Total	**96**	**96**	**479**	**479**
Ship Hulks				
HRC	6	6	14	30
SOCAL	1	1	1	5
Total	**7**	**7**	**15**	**35**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

Table 3.0-24: Number and Location of Targets Expended During Testing Activities

Activity Area	Maximum Annual # of Targets		5-Year # of Targets	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Sub-surface Targets (Stationary)				
HRC	1,234	1,234	6,166	6,166
SOCAL	178	206	889	1,026
Total	**1,412**	**1,440**	**7,055**	**7,192**
Sub-surface Targets (Mobile)				
HRC	301	336	1,489	1,680
SOCAL	450	761	2,201	3,802
Total	**751**	**1,097**	**3,690**	**5,482**
Surface Targets (Stationary)				
HRC	604	652	3,019	3,258
SOCAL	1,249	1,577	6,243	7,881
Total	**1,853**	**2,229**	**9,262**	**11,139**
Surface Targets (Mobile)				
HRC	800	818	4,000	4,087
SOCAL	1,054	1,073	5,270	5,365
Total	**1,854**	**1,891**	**9,270**	**9,452**
Mine Shapes				
HRC	4	4	18	18
SOCAL	40	46	195	229
Total	**44**	**50**	**213**	**247**
Air Targets (Decoy)				
HRC	10	10	50	50
SOCAL	24	55	120	275
Total	**34**	**65**	**170**	**325**

Table 3.0-25: Number and Location of Other Military Materials Expended During Training Activities

Activity Area	*Maximum Annual # of Materials*		*5-Year # of Materials*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Acoustic Countermeasures				
HRC	972	972	4,757	4,815
SOCAL	346	346	1,580	1,634
Transit Corridor	14	14	70	70
Total	**1,332**	**1,332**	**6,407**	**6,519**
Anchors				
HRC	3	3	15	15
SOCAL	1	1	5	5
Total	**4**	**4**	**20**	**20**
Canisters – Miscellaneous				
HRC	104	104	520	520
SOCAL	2,459	2,459	12,295	12,295
Total	**2,563**	**2,563**	**12,815**	**12,815**
Jet Assist Take Off Bottles				
HRC	39	39	195	195
SOCAL	36	36	180	180
Total	**75**	**75**	**375**	**375**
Chaff – Ship				
HRC	74	74	370	370
SOCAL	250	250	1,250	1,250
Total	**324**	**324**	**1,620**	**1,620**
Chaff – Air Cartridges				
HRC	513	513	2,565	2,565
SOCAL	3,780	3,780	18,900	18,900
Total	**4,293**	**4,293**	**21,465**	**21,465**
Endcaps				
HRC	2,057	2,057	10,285	10,285
SOCAL	11,968	11,968	59,840	59,840
Total	**14,025**	**14,025**	**70,125**	**70,125**
Flares				
HRC	1,544	1,544	7,720	7,720
SOCAL	8,188	8,188	40,940	40,940
Total	**9,732**	**9,732**	**48,660**	**48,660**
Compression Pads or Plastic Pistons				
HRC	1,482	1,482	7,410	7,410
SOCAL	8,184	8,184	40,920	40,920
Total	**9,666**	**9,666**	**48,330**	**48,330**

Table 3.0-25: Number and Location of Other Military Materials Expended During Training Activities (continued)

Activity Area	*Maximum Annual # of Materials*		*5-Year # of Materials*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Flare O-Rings				
HRC	1,544	1,544	7,720	7,720
SOCAL	8,188	8,188	40,940	40,940
Total	**9,732**	**9,732**	**48,660**	**48,660**
Expendable Bathythermographs				
HRC	713	713	3,565	3,565
SOCAL	3,480	3,480	17,040	17,400
Transit Corridor	7	7	35	35
Total	**4,200**	**4,200**	**20,640**	**21,000**
Fiber Optic Canister				
HRC	6	6	30	30
SOCAL	32	32	160	160
Total	**38**	**38**	**190**	**190**
Heavyweight Torpedo Accessories				
HRC	392	392	1,928	1,960
SOCAL	212	212	524	532
Total	**604**	**604**	**2,452**	**2,492**
Lightweight Torpedo Accessories				
HRC	48	48	240	240
SOCAL	189	189	897	897
Total	**237**	**237**	**1,137**	**1,137**
Marine Markers				
HRC	692	692	3,460	3,460
SOCAL	678	678	3,390	3,390
Transit Corridor	11	11	55	55
Total	**1,381**	**1,381**	**6,905**	**6,905**
Buoys				
HRC	13	13	51	65
SOCAL	65	73	271	365
Total	**78**	**86**	**322**	**430**
Sonobuoys				
HRC	11,004	11,004	45,598	48,810
SOCAL	23,445	24,257	110,313	118,405
Transit Corridor	120	120	600	600
Total	**34,569**	**35,381**	**156,511**	**167,815**

Table 3.0-25: Number and Location of Other Military Materials Expended During Training Activities (continued)

Activity Area	*Maximum Annual # of Materials*		*5-Year # of Materials*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Decelerators/Parachutes – Small				
HRC	11,020	11,020	45,678	48,890
SOCAL	23,574	24,386	110,958	119,050
Transit Corridor	120	120	600	600
Total	**34,714**	**35,526**	**157,236**	**168,540**
Parachutes – Medium				
HRC	62	62	310	310
SOCAL	4	4	20	20
Total	**66**	**66**	**330**	**330**
Parachutes – Large				
HRC	36	36	180	180
SOCAL	36	36	180	180
Total	**72**	**72**	**360**	**360**
Parachutes – Extra Large				
HRC	3	3	15	15

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

Table 3.0-26: Number and Location of Other Military Materials Expended During Testing Activities

Activity Area	*Maximum Annual # of Materials*		*5-Year # of Materials*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Acoustic Countermeasures				
HRC	1,607	1,607	7,878	7,878
SOCAL	1,612	1,612	7,903	7,903
Total	**3,219**	**3,219**	**15,781**	**15,781**
Anchors				
HRC	852	852	4,260	4,260
SOCAL	1,822	1,822	9,110	9,110
Total	**2,674**	**2,674**	**13,370**	**13,370**
Chaff – Ship Cartridge				
HRC	902	902	4,510	4,510
SOCAL	1,250	1,250	6,250	6,250
Total	**2,152**	**2,152**	**10,760**	**10,760**
Chaff – Air Cartridge				
HRC	2,490	2,490	12,450	12,450
SOCAL	4,660	4,660	23,300	23,300
Total	**7,150**	**7,150**	**35,750**	**35,750**

Table 3.0-26: Number and Location of Other Military Materials Expended During Testing Activities (continued)

Activity Area	*Maximum Annual # of Materials*		*5-Year # of Materials*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Endcaps				
HRC	4,980	4,980	24,900	24,900
SOCAL	8,920	8,920	44,600	44,600
Total	**13,900**	**13,900**	**69,500**	**69,500**
Flares				
HRC	2,490	2,490	12,450	12,450
SOCAL	4,260	4,260	21,300	21,300
Total	**6,750**	**6,750**	**33,750**	**33,750**
Compression Pad/Piston				
HRC	2,490	2,490	12,450	12,450
SOCAL	4,260	4,260	21,300	21,300
Total	**6,750**	**6,750**	**33,750**	**33,750**
Flare O-Rings				
HRC	2,490	2,490	12,450	12,450
SOCAL	4,260	4,260	21,300	21,300
Total	**6,750**	**6,750**	**33,750**	**33,750**
Expendable Bathythermographs				
HRC	1,156	1,156	5,765	5,780
SOCAL	1,388	1,388	6,880	6,940
Total	**2,544**	**2,544**	**12,645**	**12,720**
Fiber Optic Canister				
HRC	144	144	576	576
SOCAL	434	440	2,009	2,199
Total	**578**	**584**	**2,585**	**2,775**
Heavyweight Torpedo Accessories				
HRC	231	231	1,117	1,117
SOCAL	231	231	1,117	1,117
Total	**462**	**462**	**2,234**	**2,234**
Lightweight Torpedo Accessories				
HRC	283	283	1,316	1,331
SOCAL	449	449	2,049	2,157
Total	**732**	**732**	**3,365**	**3,488**
Non-Explosive Buoys				
HRC	404	424	1,893	2,098
SOCAL	823	853	3,943	4,243
Total	**1,227**	**1,277**	**5,836**	**6,341**

Table 3.0-26: Number and Location of Other Military Materials Expended During Testing Activities (continued)

Activity Area	*Maximum Annual # of Materials*		*5-Year # of Materials*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Non-Explosive Sonobuoys				
HRC	9,193	9,503	43,526	47,231
SOCAL	15,696	16,146	72,378	80,446
Total	**24,889**	**25,649**	**115,904**	**127,677**
Sabot				
HRC	7,400	7,400	37,000	37,000
SOCAL	7,736	7,736	38,680	38,680
Total	**15,136**	**15,136**	**75,680**	**75,680**
Decelerators/Parachutes – Small				
HRC	9,337	9,647	44,231	47,951
SOCAL	15,929	16,379	73,419	81,595
Total	**25,266**	**26,026**	**117,650**	**129,546**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

3.0.3.3.4.3 Seafloor Devices

Seafloor devices represent items used during training or testing activities that are deployed onto the seafloor and recovered. These items include moored mine shapes, recoverable anchors, bottom-placed instruments, temporary bottom cable arrays, energy harvesting devices, and robotic vehicles referred to as “crawlers.” Bottom-placed instruments usually include an anchor which may be expended while recovering the instrument. Seafloor devices are either stationary or move very slowly along the bottom and do not pose a threat to highly mobile organisms when in place; however, during the deployment process, they may pose a physical disturbance or strike risk. The effect of devices on the bottom will be discussed as an alteration of the bottom substrate and associated living resources (e.g., invertebrates and vegetation).

Table 3.0-27 shows the number and location of proposed events that include the use of seafloor devices.

Table 3.0-27: Number and Location of Events Including Seafloor Devices

Activity Area	*Maximum Annual # of Events*		*5-Year # of Events*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Training				
HRC	115	115	575	575
SOCAL	1,894	1,894	9,470	9,470
Total	**2,009**	**2,009**	**10,045**	**10,045**
Testing				
HRC	47	47	235	235
SOCAL	417	429	2,085	2,145
Total	**464**	**476**	**2,320**	**2,380**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

3.0.3.3.4.4 Aircraft

Aircraft involved in Navy training and testing activities are separated into three categories: (1) fixed-wing aircraft, (2) rotary-wing aircraft, (3) tilt-rotor aircraft, and (4) unmanned aerial systems. Fixed-wing aircraft include, but are not limited to, planes such as F-35, P-8, F/A-18, and E/A-18G. Rotary-wing aircraft are also referred to as helicopters (e.g., MH-60), and tilt-rotor aircraft include the MV-22. Unmanned aerial systems include a variety of platforms, including but not limited to, the Small Tactical Unmanned Aerial System – Tier II, Triton unmanned aerial system, Fire Scout Vertical Take-off and Landing Unmanned Aerial System, and the MQ-25 Stingray Carrier Based Unmanned Aerial System. Aircraft strikes are only applicable to birds.

Table 3.0-28 shows the number and location of proposed events that include the use of aircraft.

Table 3.0-28: Number and Location of Events Including Aircraft

Activity Area	*Maximum Annual # of Events*		*5-Year # of Events*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Training				
HRC	4,346	4,346	21,675	21,718
SOCAL	28,077	28,083	140,277	140,371
Transit Corridor	17	17	85	85
Total	**32,440**	**32,446**	**162,037**	**162,174**
Testing				
HRC	905	909	4,478	4,534
SOCAL	2,240	2,252	10,372	11,246
Total	**3,145**	**3,161**	**14,850**	**15,780**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

3.0.3.3.5 Entanglement Stressors

This section describes the entanglement stressors introduced into the water through naval training and testing, the relative magnitude and location of these activities, and provides the basis for analysis of potential impacts on resources in the remainder of Chapter 3 (Affected Environment and Environmental Consequences). To assess the entanglement risk of materials expended during training and testing, the Navy examined the characteristics of these items (e.g., size and rigidity) for their potential to entangle marine animals. For a constituent of military expended materials to entangle a marine animal the item must be flexible enough to wrap around the animal or appendages, or be trapped in the jaw or baleen. This analysis includes the potential impacts from three types of military expended materials: (1) wires and cables, (2) decelerators/parachutes, and (3) biodegradable polymer. The Navy deploys equipment designed for military purposes and strives to reduce the risk of accidental entanglement posed by any item it releases into the sea. Arresting gear cables are not an entanglement concern due to their heavy weight and thickness. These cables weigh approximately 450 lb., reach 110 ft. in length, and are several inches thick; therefore, they do not loop and are not able to wrap around an animal or appendage, and will not be discussed further in this document.

3.0.3.3.5.1 Wires and Cables

During some proposed training and testing activities, the Navy may temporarily install and remove or expend different types of wires and cables. Temporary installations could include arrays or mooring lines attached to the seafloor or to surface buoys or vessels. Because these wires and cables are generally taught while in use, and then are later recovered, they are not considered an entanglement risk to marine species. The varieties of expended wires and cables are described in the following sections.

Fiber Optic Cables

Although a portion may be recovered, some fiber optic cables used during Navy training and testing associated with remotely operated mine neutralization activities would be expended. The length of the expended tactical fiber would vary (up to about 3,000 m) depending on the activity. Tactical fiber has an 8-micrometer (µm) (0.008 millimeter [mm]) silica core and acylate coating, and looks and feels like thin monofilament fishing line. Other characteristics of tactical fiber are a 242 µm (0.24 mm) diameter, 12 lb. tensile strength, and 3.4 mm bend radius (Corning Incorporated, 2005; Raytheon Company, 2015). Tactical fiber is relatively brittle; it readily breaks if knotted, kinked, or abraded against a sharp object. Deployed tactical fiber will break if looped beyond its bend radius (3.4 mm), or exceeds its tensile strength (12 lb.). If the fiber becomes looped around an underwater object or marine animal, it will not tighten unless it is under tension. Such an event would be unlikely based on its method of deployment and its resistance to looping after it is expended. The tactical fibers are often designed with controlled buoyancy to minimize the fiber's effect on vehicle movement. The tactical fiber would be suspended within the water column during the activity, and then be expended and sink to the seafloor (effective sink rate of 1.45 cm/second) (Raytheon Company, 2015) where it would be susceptible to abrasion and burial by sedimentation.

In addition to expended fiber optic cables, the Navy proposes to temporarily deploy slightly negatively buoyant fiber optic cables at depths of approximately 600 to 850 ft. up to approximately 60 mi. in length. These cables are designed to resist coiling when unspooled, and breaking strength would be approximately 50 to 90 lb. These fiber optic cables would be recovered following their use.

Guidance Wires

Guidance wires are used during heavy-weight torpedo firings to help the firing platform control and steer the torpedo. They trail behind the torpedo as it moves through the water. Finally, the guidance wire is released from both the firing platform and the torpedo and sinks to the ocean floor.

The torpedo guidance wire is a single-strand, thin gauge, coated copper alloy. The tensile breaking strength of the wire is a maximum of 40.4 lb. and can be broken by hand (Environmental Sciences Group, 2005; National Marine Fisheries Service, 2008; Swope & McDonald, 2013), contrasting with the rope or lines associated with commercial fishing towed gear (trawls), stationary gear (traps), or entanglement gear (gillnets) that use lines with substantially higher (up to 500–2,000 lb.) breaking strength as their “weak links.” However, it has a somewhat higher breaking strength than the monofilament used in the body of most commercial gillnets (typically 31 lb. or less). The resistance to looping and coiling suggest that torpedo guidance wire does not have a high entanglement potential compared to other entanglement hazards (Swope & McDonald, 2013). Torpedo guidance wire sinks at a rate of 0.24 m per second (Swope & McDonald, 2013).

Sonobuoy Wire

Sonobuoys consist of a surface antenna and float unit and a subsurface hydrophone assembly unit. The two units are attached through a thin-gauge, dual-conductor, and hard-draw copper strand wire, which is then wrapped by a hollow rubber tubing or bungee in a spiral configuration. The tensile breaking strength of the wire and rubber tubing is no more than 40 lb. The length of the wire is housed in a plastic canister dispenser, which remains attached upon deployment. The length of wire that extends out is no more than 1,500 ft. and is dependent on the water depth and type of sonobuoy. Attached to the wire is a kite-drogue and damper disk stabilizing system made of non-woven nylon fabric. The nylon fabric is very thin and can be broken by hand. The wire runs through the stabilizing system, and leads to the hydrophone components. The hydrophone components may be covered by thin plastic netting depending on type of sonobuoy, but pose no entanglement risk. Each sonobuoy has a saltwater activated polyurethane float that inflates when the sonobuoy is submerged and keeps the sonobuoy components floating vertically in the water column below it. Sonobuoys remain suspended in the water column for no more than 30 hours, after which they sink to the seafloor.

Bathythermographs are similar to sonobuoys in that they consist of a subsurface unit (to measure temperature of the water column in the case of the bathythermograph) that is connected by wire to the float unit (for air-deployed bathythermographs) or directly to the ship (for ship-deployed bathythermographs). The bathythermograph wire is similar to the sonobuoy wire as described above.

Table 3.0-29 and Table 3.0-30 show the number and location of wires and cables expended during proposed training and testing activities.

Table 3.0-29: Number and Location of Wires and Cables Expended During Training Activities

Activity Area	*Maximum Annual # of Materials*		*5-Year # of Materials*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Fiber Optic Cables				
HRC	6	6	30	30
SOCAL	32	32	160	160
Total	**38**	**38**	**190**	**190**
Guidance Wires				
HRC	392	392	1,928	1,960
SOCAL	212	212	524	532
Total	**604**	**604**	**2,452**	**2,492**
Sonobuoy Wires				
HRC	11,004	11,004	45,598	48,810
SOCAL	23,445	24,257	110,313	118,405
Transit Corridor	120	120	600	600
Total	**34,569**	**35,381**	**156,511**	**167,815**
Expendable Bathythermograph Wires				
HRC	713	713	3,565	3,565
SOCAL	3,480	3,480	17,040	17,400
Transit Corridor	7	7	35	35
Total	**4,200**	**4,200**	**20,640**	**21,000**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

Table 3.0-30: Number and Location of Wires and Cables Expended During Testing Activities

Activity Area	*Maximum Annual # of Materials*		*5-Year # of Materials*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Fiber Optic Cables				
HRC	144	144	576	576
SOCAL	434	440	2,009	2,199
Total	**578**	**584**	**2,585**	**2,775**
Guidance Wires				
HRC	231	231	1,117	1,117
SOCAL	231	231	1,117	1,117
Total	**462**	**462**	**2,234**	**2,234**
Sonobuoy Wires				
HRC	9,193	9,503	43,526	47,231
SOCAL	15,696	16,146	72,378	80,446
Total	**24,889**	**25,649**	**115,904**	**127,677**
Expendable Bathythermograph Wires				
HRC	1,156	1,156	5,765	5,780
SOCAL	1,388	1,388	6,880	6,940
Total	**2,544**	**2,544**	**12,645**	**12,720**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

3.0.3.3.5.2 Decelerators/Parachutes

Decelerators/parachutes used during training and testing activities are classified into four different categories based on size: small, medium, large, and extra-large (Table 3.0-31). Aircraft-launched sonobuoys and lightweight torpedoes (such as the MK 46 and MK 54) use nylon decelerators/parachutes ranging in size from 18 to 72 in. in diameter (small). The majority of the decelerators/parachutes in the small size category are smaller (18 in.) cross shape decelerators/parachutes associated with sonobuoys (Figure 3.0-16). The small size category also includes drag parachutes associated with some aerial drones, which are described more fully below. Illumination flares use medium decelerators/parachutes, up to approximately 19 ft. in diameter. Both small- and medium-sized decelerators/parachutes are made of cloth and nylon, many with weights attached to their short attachment lines to speed their sinking. At water impact, the decelerator/parachute assembly is expended and sinks away from the unit. The decelerator/parachute assembly may remain at the surface for 5–15 seconds before the decelerator/parachute and its housing sink to the seafloor, where it becomes flattened (Environmental Sciences Group, 2005). Once settled on the bottom the canopy may temporarily billow if bottom currents are present.

Figure 3.0-16: Sonobuoy Launch Depicting the Relative Size of a Decelerator/Parachute

Table 3.0-31: Size Categories for Decelerators/Parachutes Expended During Training and Testing Events

Size Category	*Diameter (ft.)*	*Associated Activity*
Small	1.5–6	Air-launched sonobuoys, lightweight torpedoes, and drones (drag decelerator/parachute)
Medium	19	Illumination flares
Large	30–50	Drones (main decelerator/parachute)
Extra-large	82	Drones (main decelerator/parachute)

Aerial targets (drones) use large (between 30 and 50 ft. in diameter) and extra-large (80 ft. in diameter) decelerators/parachutes (Figure 3.0-17). Large and extra-large decelerators/parachutes are also made of cloth and nylon, with suspension lines of varying lengths (large: 40–70 ft. in length [with up to 28 lines per decelerator/parachute]; extra-large: 82 ft. in length [with up to 64 lines per decelerator/parachute]). Some aerial targets also use a small drag parachute (6 ft. in diameter) to slow their forward momentum prior to deploying the larger primary decelerator/parachute. Unlike the small- and medium-sized decelerators/parachutes, drone decelerators/parachutes do not have weights attached and may remain at the surface or suspended in the water column for some time prior to eventual settlement on the seafloor.

Figure 3.0-17: Aerial Target (Drone) with Parachute Deployed

Table 3.0-25 and Table 3.0-26 show the number and location of decelerator/parachutes expended during proposed training and testing activities.

3.0.3.3.5.3 Biodegradable Polymer

Marine Vessel Stopping payloads are systems designed to deliver the appropriate measure(s) to affect a vessel's propulsion and associated control surfaces to significantly slow and potentially stop the advance of the vessel. Marine Vessel Stopping proposed activities include the use of biodegradable polymers designed to entangle the propellers of in-water vessels. Biodegradable polymers degrade to smaller compounds as a result of microorganisms and enzymes. The biodegradable polymers that the Navy uses are designed to temporarily interact with the propeller(s) of a target craft rendering it ineffective. Some of the polymer constituents would dissolve within two hours of immersion. Based on the constituents of the biodegradable polymer the Navy proposes to use, it is anticipated that the material will break down into small pieces within a few days to weeks. This will break down further and dissolve into the water column within weeks to a few months. Degradation and dispersal timelines are influenced by water temperature, currents, and other oceanographic features. Overall, the longer the polymer remains in the water, the weaker it becomes making it more brittle and likely to break. At the end of dispersion, the remaining materials are generally separated fibers with lengths on the order of 54 micrometers.

Biodegradable polymers will be used only during proposed testing activities, not during training activities. Table 3.0-32 shows the number and location of Marine Vessel Stopping payloads that use biodegradable polymer.

Table 3.0-32: Number and Location of Marine Vessel Stopping Payloads that use Biodegradable Polymer

Activity Area	Maximum Annual # of Payloads		5-Year # of Payloads	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Testing				
HRC	210	210	1,050	1,050
SOCAL	300	300	1,500	1,500
Total	**510**	**510**	**2,550**	**2,550**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

3.0.3.3.6 Ingestion Stressors

This section describes the ingestion stressors introduced into the water through naval training and testing and the relative magnitude and location of these activities in order to provide the basis for analysis of potential impacts on resources in the remainder of Chapter 3 (Affected Environment and Environmental Consequences). To assess the ingestion risk of materials expended during training and testing, the Navy examined the characteristics of these items (such as buoyancy and size) for their potential to be ingested by marine animals in the Study Area. The Navy expends the following types of materials that could become ingestion stressors during training and testing in the Study Area: non-explosive practice munitions (small- and medium-caliber), fragments from high-explosives, fragments from targets, chaff, flare casings (including plastic end caps and pistons), and some decelerators/parachutes. Other military expended materials such as targets, large-caliber projectiles, intact training and testing bombs, guidance wires, 55-gallon drums, sonobuoy tubes, and marine markers are too large for marine organisms to consume and are eliminated from further discussion regarding ingestion.

Solid metal materials, such as small-caliber projectiles or fragments from high-explosive munitions, sink rapidly to the seafloor. Lighter plastic items may be caught in currents and gyres or entangled in floating kelp and could remain in the water column for hours to weeks or indefinitely before sinking (e.g., plastic end caps [from chaff cartridges] or plastic pistons [from flare cartridges]).

3.0.3.3.6.1 Non-Explosive Practice Munitions

Only small- or medium-caliber projectiles and flechettes (small metal darts) from some non-explosive rockets would be small enough for marine animals to ingest. This would vary depending on the resource and will be discussed in more detail within each resource section. Small- and medium-caliber projectiles include all sizes up to and including those that are 2.25 in. in diameter. Flechettes from some non-explosive rockets are approximately 2 in. in length. Each non-explosive flechette rocket contains approximately 1,180 individual flechettes that are released. These solid metal materials would quickly move through the water column and settle to the seafloor. Tables 3.0-19 and 3.0-20 shows the number and location of non-explosive practice munitions used during proposed training and testing activities.

3.0.3.3.6.2 Fragments from High-Explosive Munitions

Many different types of high-explosive munitions can result in fragments that are expended at sea during training and testing activities.

Types of high-explosive munitions that can result in fragments include torpedoes, neutralizers, grenades, projectiles, missiles, rockets, buoys, sonobuoys, anti-torpedo countermeasures, mines, and bombs. Fragments would result from fractures in the munitions casing and would vary in size depending on the size of the net explosive weight and munition type; typical sizes of fragments are unknown. These solid metal materials would quickly sink through the water column and settle to the seafloor.

Table 3.0-33 and Table 3.0-34 show the number and location of explosives used during training and testing activities that may result in fragments.

3.0.3.3.6.3 Military Expended Materials Other Than Munitions

Several different types of materials other than munitions are expended at sea during training and testing activities.

Target-Related Materials

At-sea targets are usually remotely operated airborne, surface, or subsurface traveling units, many of which are designed to be recovered for reuse. However, if they are used during activities that use high-explosives then they may result in fragments and ultimate loss of the target. Expendable targets that may result in fragments would include air-launched decoys, surface targets (e.g., marine markers, cardboard boxes, and 10 ft. diameter red balloons), and mine shapes. Most target fragments would sink quickly to the seafloor. Floating material, such as Styrofoam, may be lost from target boats and remain at the surface for some time. Only targets that may result in smaller fragments are included in the analyses of ingestion potential.

There are additional types of targets discussed previously, but only surface targets, air targets, ship hulks, and mine shapes would be expected to result in fragments when high-explosive munitions are used. Table 3.0-33 and Table 3.0-34 show the number and location of targets used during proposed training and testing activities that may result in fragments.

Table 3.0-33: Number and Location of Targets Expended During Training Activities That May Result in Fragments

Activity Area	*Maximum Annual # of Targets*		*5-Year # of Targets*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Air Targets (Decoy)				
HRC	2,078	2,078	10,388	10,388
SOCAL	14	14	69	69
Transit Corridor	30	30	150	150
Total	**2,122**	**2,122**	**10,607**	**10,607**
Air Targets (Drone)				
HRC	16	16	76	76
SOCAL	2	2	10	10
Total	**18**	**18**	**86**	**86**
Mine Shapes				
HRC	13	13	64	64
SOCAL	83	83	415	415
Total	**96**	**96**	**479**	**479**

Table 3.0-33: Number and Location of Targets Expended During Training Activities That May Result in Fragments (continued)

Activity Area	Maximum Annual # of Targets		5-Year # of Targets	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Surface Targets (Stationary)				
HRC	312	484	1,560	2,419
SOCAL	605	669	3,024	3,341
Transit Corridor	43	77	213	381
Total	**960**	**1,230**	**4,797**	**6,141**
Surface Targets (Mobile)				
HRC	1,398	1,398	6,989	6,989
SOCAL	3,466	3,466	17,329	17,329
Transit Corridor	132	132	658	658
Total	**4,996**	**4,996**	**24,976**	**24,976**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

Table 3.0-34: Number and Location of Targets Expended During Testing Activities That May Result in Fragments

Activity Area	Maximum Annual # of Targets		5-Year # of Targets	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Air Targets (Decoy)				
HRC	10	10	50	50
SOCAL	24	55	120	275
Total	**34**	**65**	**170**	**325**
Air Targets (Drone)				
HRC	190	196	948	976
SOCAL	877	1,199	4,382	5,993
Total	**1,067**	**1,395**	**5,330**	**6,969**
Surface Targets (Stationary)				
HRC	604	652	3,019	3,258
SOCAL	1,249	1,577	6,243	7,881
Total	**1,853**	**2,229**	**9,262**	**11,139**
Surface Targets (Mobile)				
HRC	800	818	4,000	4,087
SOCAL	1,054	1,073	5,365	5,365
Total	**1,854**	**1,891**	**9,365**	**9,452**
Mine Shapes				
HRC	4	4	18	18
SOCAL	40	46	195	229
Total	**44**	**50**	**213**	**247**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

Chaff

Chaff consists of reflective, aluminum-coated glass fibers used to obscure ships and aircraft from radar-guided systems. Chaff, which is stored in canisters, is either dispensed from aircraft or fired into the air from the decks of surface ships when an attack is imminent. The glass fibers create a radar cloud that mask the position of the ship or aircraft. Chaff is composed of an aluminum alloy coating on glass fibers of silicon dioxide (U.S. Department of the Air Force, 1997). Chaff is released or dispensed in cartridges or projectiles that contain millions of fibers. When deployed, a diffuse cloud of fibers is formed that is undetectable to the human eye. Chaff is a very light material, similar to fine human hair. It can remain suspended in air anywhere from 10 minutes to 10 hours and can travel considerable distances from its release point, depending on prevailing atmospheric conditions (Arfsten et al., 2002; U.S. Department of the Air Force, 1997). Doppler radar has tracked chaff plumes containing approximately 900 g of chaff drifting 200 mi. from the point of release, with the plume covering greater than 400 mi.^{3} (Arfsten et al., 2002).

The chaff concentrations that marine animals could be exposed to following the release of multiple cartridges (e.g., following a single day of training) is difficult to accurately estimate because it depends on several variable factors. First, specific release points are not recorded and tend to be random, and chaff dispersion in air depends on prevailing atmospheric conditions. After falling from the air, chaff fibers would be expected to float on the sea surface for some period, depending on wave and wind action. The fibers would be dispersed farther by sea currents as they float and slowly sink toward the bottom. Chaff concentrations in benthic habitats following the release of a single cartridge would be lower than the values noted in this section, based on dispersion by currents and the dilution capacity of the ocean.

Several literature reviews and controlled experiments indicate that chaff poses little risk to organisms, except at concentrations substantially higher than those that could reasonably occur from military training (Arfsten et al., 2002; U.S. Department of the Air Force, 1997; U.S. Department of the Navy, 1999). Nonetheless, some marine animal species within the Study Area could be exposed to chaff through direct body contact, inhalation, and ingestion. Chemical alteration of water and sediment from decomposing chaff fibers is not expected to occur. Based on the dispersion characteristics of chaff, it is likely that marine animals would occasionally come in direct contact with chaff fibers while either at the water's surface or while submerged, but such contact would be inconsequential. Because of the flexibility and softness of chaff, external contact would not be expected to impact most wildlife (U.S. Department of the Air Force, 1997) and the fibers would quickly wash off shortly after contact. Given the properties of chaff, skin irritation is not expected to be a problem (U.S. Department of the Air Force, 1997). The potential exists for marine animals to inhale chaff fibers if they are at the surface while chaff is airborne. Arfsten et al. (2002), U.S. Department of the Navy (1999), and U.S. Department of the Air Force (1997) reviewed the potential impacts of chaff inhalation on humans, livestock, and other animals and concluded that the fibers are too large to be inhaled into the lungs. The fibers were predicted to be deposited in the nose, mouth, or trachea and either swallowed or expelled.

In laboratory studies conducted by the University of Delaware (U.S. Department of the Navy, 1999), blue crabs and killifish were fed a food-chaff mixture daily for several weeks, and no significant mortality was observed at the highest exposure treatment. Similar results were found when chaff was added directly to exposure chambers containing filter-feeding menhaden. Histological examination indicated no damage from chaff exposures. A study on cow calves that were fed chaff found no evidence of digestive disturbance or other clinical symptoms (U.S. Department of the Air Force, 1997).

Chaff cartridge plastic end caps and pistons would also be released into the marine environment, where they would persist for long periods and could be ingested by marine animals. Chaff end caps and pistons sink in saltwater (Spargo, 2007).

Table 3.0-25 and Table 3.0-26 show the number and location of chaff cartridges used during training and testing activities.

Flares

Flares are pyrotechnic devices used to defend against heat-seeking missiles, where the missile seeks out the heat signature from the flare rather than the aircraft's engines. Similar to chaff, flares are also dispensed from aircraft. The flare device consists of a cylindrical cartridge approximately 1.4 in. in diameter and 5.8 in. in length. Flares are designed to burn completely. The only material that would enter the water would be a small, round, plastic compression pad or piston (0.45–4.1 g depending on flare type). The flare pads and pistons float in sea water.

An extensive literature review and controlled experiments conducted by the U.S. Air Force revealed that self-protection flare use poses little risk to the environment or animals (U.S. Department of the Air Force, 1997).

Table 3.0-25 and Table 3.0-26 shows the number and location of flares expended during training and testing activities.

Decelerators/Parachutes

Decelerators/parachutes are expended with the use of sonobuoys, lightweight torpedoes, and illumination flares. Only the small-size decelerators/parachutes expended with sonobuoys and lightweight torpedoes pose an ingestion risk to marine life. See Section 3.0.3.3.5.2 (Decelerators/Parachutes) above for a complete description.

Table 3.0-35 and Table 3.0-36 show the number and location of small-size decelerators/parachutes expended during proposed training and testing activities.

Table 3.0-35: Number and Location of Decelerators/Parachutes Expended During Training Activities

Activity Area	*Maximum Annual # of Decelerators/Parachutes*		*5-Year # of Decelerators/Parachutes*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Decelerators/Parachutes – Small				
HRC	11,020	11,020	45,678	48,890
SOCAL	23,574	24,386	110,958	119,050
Transit Corridor	120	120	600	600
Total	**34,714**	**35,526**	**157,236**	**168,540**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

Table 3.0-36: Number and Location of Decelerators/Parachutes Expended During Testing Activities

Activity Area	Maximum Annual # of Decelerators/Parachutes		5-Year # of Decelerators/Parachutes	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Decelerators/Parachutes – Small				
HRC	9,337	9,647	44,231	47,951
SOCAL	15,929	16,379	73,419	81,595
Total	**25,266**	**26,026**	**117,650**	**129,546**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex)

3.0.3.4 Resource-Specific Impacts Analysis for Individual Stressors

The direct and indirect impacts of each stressor are analyzed in each resource section for which there may be an impact. Quantitative methods were used to the extent possible, but data limitations required the use of qualitative methods for most stressor/resource interactions. Resource-specific methods are described in sections of Chapter 3 (Affected Environment and Environmental Consequences), where applicable. While specific methods used to analyze the impacts of individual stressors varied by resource, the following generalized approach was used for all stressor/resource interactions:

- The frequency, duration, and spatial extent of exposure to stressors were analyzed for each resource. The frequency of exposure to stressors or frequency of a proposed activity was characterized as intermittent or continuous, and was quantified in terms of number per unit of time when possible. Duration of exposure was expressed as short or long term and was quantified in units of time (e.g., seconds, minutes, and hours) when possible. The spatial extent of exposure was generally characterized as widespread or localized, and the stressor footprint or area (e.g., square feet, square nautical miles) was quantified when possible.
- An analysis was conducted to determine whether and how resources are likely to respond to stressor exposure or be altered by stressor exposure based upon available scientific knowledge. This step included reviewing available scientific literature and empirical data. For many stressor/resource interactions, a range of likely responses or endpoints was identified. For example, exposure of an organism to sound produced by an underwater explosion could result in no response, a physiological response such as increased heart rate, a behavioral response such as being startled, or injury.
- The information obtained was used to analyze the likely impacts of individual stressors on a resource and to characterize the type, duration, and intensity (severity) of impacts. The type of impact was generally defined as beneficial or adverse and was further defined as a specific endpoint (e.g., change in behavior, mortality, change in concentration, loss of habitat, loss of fishing time). When possible, the endpoint was quantified. The duration of an impact was generally characterized as short term (e.g., minutes, days, weeks, months, depending on the resource), long-term (e.g., months, years, decades, depending on the resource), or permanent. The intensity of an impact was then determined. For biological resources, the analysis started with individual organisms and their habitats, and then addressed populations, species, communities, and representative ecosystem characteristics, as appropriate.

3.0.3.5 Resource-Specific Impacts Analysis for Multiple Stressors

The stressors associated with the proposed training and testing activities could affect the environment individually or in combination. The impacts of multiple stressors may be different when considered collectively rather than individually. Therefore, following the resource-specific impacts analysis for individual stressors, the combined impacts of all stressors were analyzed for that resource. This step determines the overall impacts of the alternatives on each resource, and it considers the potential for impacts that are additive (where the combined impacts on the resource are equal to the sum of the individual impacts), synergistic (where impacts combine in such a way as to amplify the effect on the resource), and antagonistic (where impacts will cancel each other out or reduce a portion of the effect on the resource). This analysis helps inform the cumulative impacts analysis and make overall impact conclusions for each resource.

Evaluating the combined impacts of multiple stressors can be complex, especially when the impacts associated with a stressor are hard to measure. Therefore, some general assumptions were used to help determine the potential for individual stressors to contribute to combined impacts. For this analysis, combined impacts were considered more likely to occur in the following situations:

- Stressors co-occur in time and space, causing a resource to be simultaneously affected by more than one stressor.
- A resource is repeatedly affected by multiple stressors or is re-exposed before fully recovering from a previous exposure.
- The impacts of individual stressors are permanent or long term (years or decades) versus short term (minutes, days, or months).
- The intensity of the impacts from individual stressors contributes to a combined overall adverse impact.

The resource-specific impacts analysis for multiple stressors included the following steps:

- Information obtained from the analysis of individual stressors was used to develop a conceptual model to predict the combined impacts of all stressors on each resource. This conceptual model incorporated factors such as the co-occurrence of stressors in space and time; the impacts or assessment endpoints of individual stressors (e.g., mortality, injury, changes in animal behavior or physiology, habitat alteration, or changes in human use); and the duration and intensity of the impacts of individual stressors.
- To the extent possible, additive impacts on a given resource were considered by summing the impacts of individual stressors. This summation was only possible for stressors with identical and quantifiable assessment endpoints. For example, if one stressor disturbed 0.25 NM^2 of benthic habitat, a second stressor disturbed 0.5 NM^2, and all other stressors did not disturb benthic habitat, then the total benthic habitat disturbed would be 0.75 NM^2. For stressors with identical but not quantifiable assessment endpoints, available scientific knowledge, best professional judgment, and the general assumptions outlined above were used to evaluate potential additive impacts.
- For stressors with differing impacts and assessment endpoints, the potential for additive, synergistic, and antagonistic effects were evaluated based on available scientific knowledge, professional judgment, and the general assumptions outlined above.

A cumulative impact is the impact on the environment that results when the incremental impact of an action is added to other past, present, and reasonably foreseeable future actions. The cumulative impacts analysis (Chapter 4, Cumulative Impacts) considers other actions regardless of what agency (Federal or non-Federal) or person undertakes the actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 Code of Federal Regulations section 1508.7). The goal of the analysis is to provide the decision makers with information relevant to reasonably foresee potentially significant impacts. See Chapter 4 (Cumulative Impacts) for the specific approach used for determining cumulative impacts.

3.0.3.6 Biological Resource Methods

The analysis of impacts on biological resources focused on the likelihood of encountering the stressor, the primary stimulus, response, and recovery of individual organisms. Where appropriate, the potential of a biological resource to overlap with a stressor was analyzed with consideration given to the specific geographic area (large marine ecosystems, open ocean areas, range complexes, OPAREAs, and other training and testing areas) in which the overlap could occur. Additionally, the differential impacts of training versus testing activities that introduce stressors to the resource were considered.

For each of the non-biological resources considered in this EIS/OEIS, the methods are unique to each specific resource and are therefore described in each resource section. For Air Quality see Section 3.1.1.1 (Methods), for Sediments and Water Quality see Section 3.2.1.2 (Methods), for Cultural Resources see Section 3.10.1.3 (Methods), for Socioeconomics see Section 3.11.1 (Introduction and Methods), and for Public Health and Safety see the Methods discussion under Section 3.12.1 (Introduction).

3.0.3.6.1 Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities

This conceptual framework describes the potential effects from exposure to acoustic and explosive activities and the accompanying short-term costs to the animal (e.g., expended energy or missed feeding opportunity). It then outlines the conditions that may lead to long-term consequences for the individual if the animal cannot fully recover from the short-term costs and how these in turn may affect the population. Within each biological resource section (e.g., marine mammals, birds, and fishes) the detailed methods to predict effects on specific taxa are derived from this conceptual framework.

An animal is considered “exposed” to a sound if the received sound level at the animal’s location is above the background ambient noise level within a similar frequency band. A variety of effects may result from exposure to acoustic and explosive activities.

The categories of potential effects are:

- ***Injury and other non-auditory injury*** *- Injury to organs or tissues of an animal.*
- ***Hearing loss*** *- A noise-induced decrease in hearing sensitivity which can be either temporary or permanent and may be limited to a narrow frequency range of hearing.*
- ***Masking*** *- When the perception of a biologically important sound (i.e., signal) is interfered with by a second sound (i.e., noise).*
- ***Physiological stress*** *- An adaptive process that helps an animal cope with changing conditions; although, too much stress can result in physiological problems.*

- ***Behavioral response** - A reaction ranging from very minor and brief changes in attentional focus, changes in biologically important behaviors, and avoidance of a sound source or area, to aggression or prolonged flight.*

Figure 3.0-18 is a flowchart that diagrams the process used to evaluate the potential effects to marine animals exposed to sound-producing activities. The shape and color of each box on the flowchart represent either a decision point in the analysis (green diamonds); specific processes such as responses, costs, or recovery (blue rectangles); external factors to consider (purple parallelograms); and final outcomes for the individual or population (orange ovals and rectangles). Each box is labeled for reference throughout the following sections. For simplicity, sound is used here to include not only sound waves but also blast waves generated from explosive sources. Box A1, the Sound-Producing Activity, is the source of this stimuli and therefore the starting point in the analysis.

The first step in predicting whether an activity is capable of affecting a marine animal is to define the stimuli experienced by the animal. The stimuli include the overall level of activity, the surrounding acoustical environment, and characteristics of the sound when it reaches the animal.

Sounds emitted from a sound-producing activity (Box A1) travel through the environment to create a spatially variable sound field. The received sound by the animal (Box A2) determines the range of possible effects. The received sound can be evaluated in several ways, including number of times the sound is experienced (repetitive exposures), total received energy, or highest SPL experienced.

Sounds that are higher than the ambient noise level and within an animal's hearing sensitivity range (Box A3) have the potential to cause effects. There can be any number of individual sound sources in a given activity, each with its own unique characteristics. For example, a Navy training exercise may involve several ships and aircraft using several types of sonar. Environmental factors such as temperature and bottom type impact how sound spreads and attenuates through the environment. Additionally, independent of the sounds, the overall level of activity and the number and movement of sound sources are important to help predict the probable reactions.

The magnitude of the responses is based on the characteristics of the acoustic stimuli and the characteristics of the animal (species, susceptibility, life history stage, size, and past experiences). Very high exposure levels close to explosives have the potential to cause injury. High-level, long-duration, or repetitive exposures may potentially cause some hearing loss. All perceived sounds may lead to behavioral responses, physiological stress, and masking. Many sounds, including sounds that are not detectable by the animal, could have no effect (Box A4).

3.0.3.6.1.1 Injury

Injury (Box B1) refers to the direct injury of tissues and organs by shock or pressure waves impinging upon or traveling through an animal's body. Marine animals are well adapted to large, but relatively slow, hydrostatic pressure changes that occur with changing depth. However, injury may result from exposure to rapid pressure changes, such that the tissues do not have time to adequately adjust.

Therefore, injury is normally limited to relatively close ranges from explosions. Injury can be mild and fully recoverable or, in some cases, lead to mortality.

Injury includes both auditory and non-auditory injury. Auditory injury is the direct mechanical injury to hearing-related structures, including tympanic membrane rupture, disarticulation of the middle ear ossicles, and injury to the inner ear structures such as the organ of Corti and the associated hair cells.

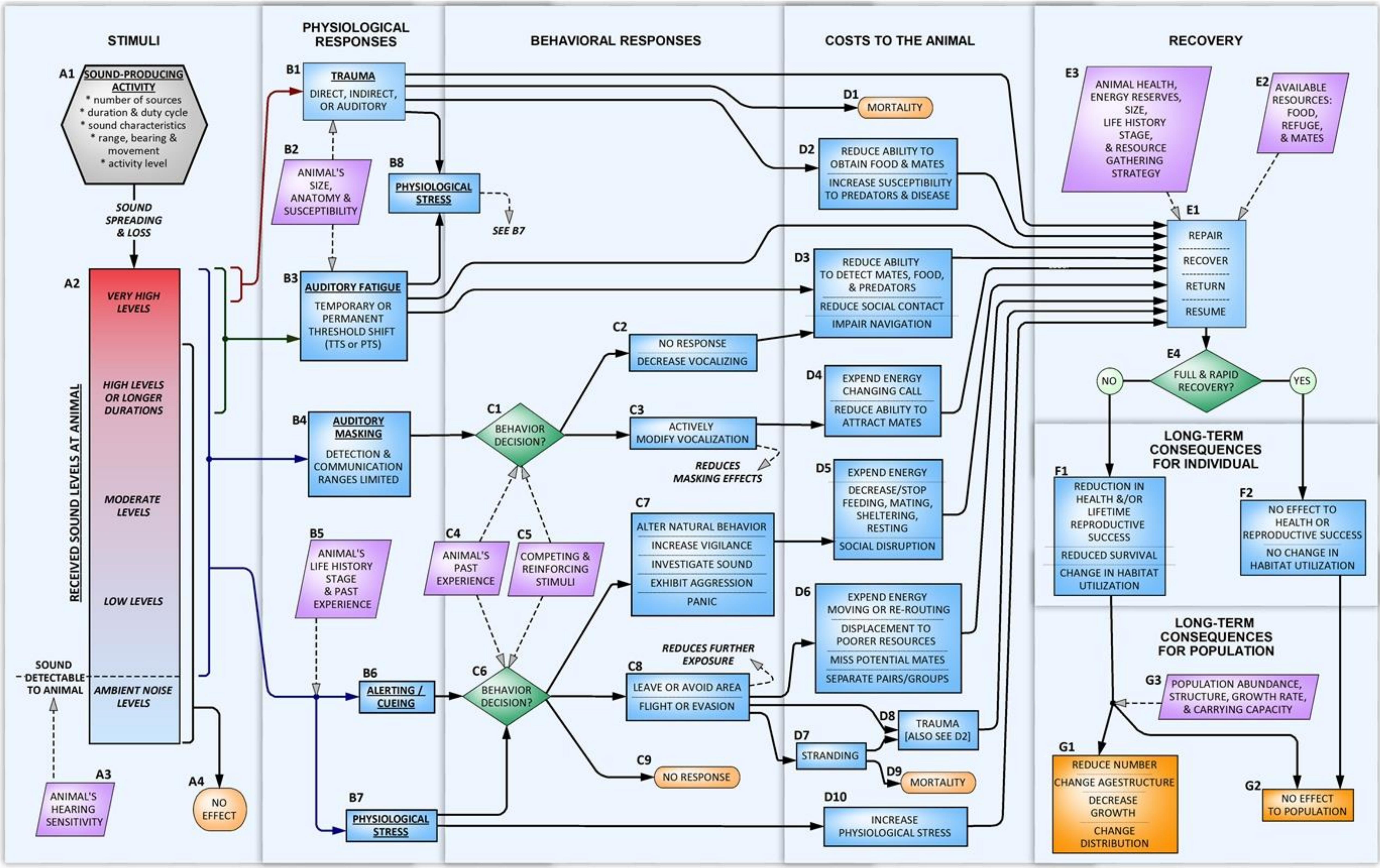

Figure 3.0-18: Flow Chart of the Evaluation Process of Sound-Producing Activities

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Auditory injury differs from auditory fatigue in that the latter involves the overstimulation of the auditory system at levels below those capable of causing direct mechanical damage. Auditory injury is always injurious but can be temporary. One of the most common consequences of auditory injury is hearing loss.

Non-auditory injury can include hemorrhaging of small blood vessels and the rupture of gas-containing tissues such as the lung, swim bladder, or gastrointestinal tract. After the ear (or other sound-sensing organs), these are usually the organs and tissues most sensitive to explosive injury. An animal's size and anatomy are important in determining its susceptibility to non-auditory injury (Box B2). Larger size indicates more tissue to protect vital organs. Therefore, larger animals should be less susceptible to injury than smaller animals. In some cases, acoustic resonance of a structure may enhance the vibrations resulting from noise exposure and result in an increased susceptibility to injury. The size, geometry, and material composition of a structure determine the frequency at which the object will resonate. Because most biological tissues are heavily damped, the increase in susceptibility from resonance is limited.

Vascular and tissue bubble formation resulting from sound exposure is a hypothesized mechanism of injury to breath-holding marine animals. Bubble formation and growth due to direct sound exposure have been hypothesized (Crum & Mao, 1996; Crum et al., 2005); however, the experimental laboratory conditions under which these phenomena were observed would not be replicated in the wild. Certain dive behaviors by breath-holding animals are predicted to result in conditions of blood nitrogen super-saturation, potentially putting an animal at risk for decompression sickness (Fahlman et al., 2014), although this phenomena has not been observed (Houser et al., 2009). In addition, animals that spend long periods of time at great depths are predicted to have super-saturated tissues that may slowly release nitrogen if the animal then spends a long time at the surface (i.e., stranding) (Houser et al., 2009).

Injury could increase the animal's physiological stress (Box B8), which feeds into the stress response (Box B7) and also increases the likelihood or severity of a behavioral response. Injury may reduce an animal's ability to secure food by reducing its mobility or the efficiency of its sensory systems, making the injured individual less attractive to potential mates, increasing an individual's chances of contracting diseases, falling prey to a predator (Box D2), or increasing an animal's overall physiological stress level (Box D10). Severe injury can lead to the death of the individual (Box D1).

Damaged tissues from mild to moderate injury may heal over time. The predicted recovery of direct injury is based on the severity of the injury, availability of resources, and characteristics of the animal. The animal may also need to recover from any potential costs due to a decrease in resource gathering efficiency and any secondary effects from predators or disease. Severe injuries can lead to reduced survivorship (longevity), elevated stress levels, and prolonged alterations in behavior that can reduce an animal's lifetime reproductive success. An animal with decreased energy stores or a lingering injury may be less successful at mating for one or more breeding seasons, thereby decreasing the number of offspring produced over its lifetime.

3.0.3.6.1.2 Hearing Loss

Hearing loss, also called a noise-induced threshold shift, is possibly the most studied type of effect from sound exposures to animals. Hearing loss manifests itself as loss in hearing sensitivity across part of an animal's hearing range, which is dependent upon the specifics of the noise exposure. Hearing loss may be either PTS, or TTS. If the threshold shift eventually returns to zero (the animal's hearing returns to pre-exposure value), the threshold shift is a TTS. If the threshold shift does not return to zero but leaves some finite amount of threshold shift, then that remaining threshold shift is a PTS. Figure 3.0-19 shows one hypothetical threshold shift that completely recovers, a TTS, and one that does not completely recover, leaving some PTS.

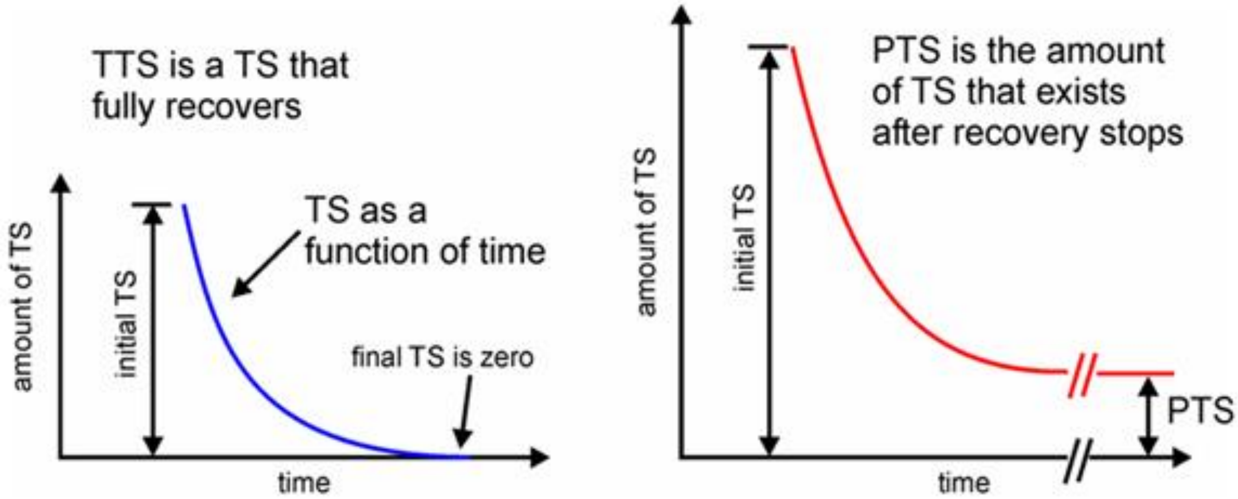

Figure 3.0-19: Two Hypothetical Threshold Shifts

The characteristics of the received sound stimuli are used and compared to the animal's hearing sensitivity and susceptibility to noise (Box A3) to determine the potential for hearing loss. The amplitude, frequency, duration, and temporal pattern of the sound exposure are important parameters for predicting the potential for hearing loss over a specific portion of an animal's hearing range. Duration is particularly important because hearing loss increases with prolonged exposure time. Longer exposures with lower sound levels can cause more threshold shift than a shorter exposure using the same amount of energy overall. The frequency of the sound also plays an important role. Experiments show that animals are most susceptible to hearing loss (Box B3) within their most sensitive hearing range. Sounds outside of an animal's audible frequency range do not cause hearing loss.

The mechanisms responsible for hearing loss may consist of a variety of mechanical and biochemical processes in the inner ear, including physical damage or distortion of the tympanic membrane (not including tympanic membrane rupture which is considered auditory injury), physical damage or distortion of the cochlear hair cells, hair cell death, changes in cochlear blood flow, and swelling of cochlear nerve terminals (Henderson et al., 2006; Kujawa & Liberman, 2009). Although the outer hair cells are the most prominent target for fatigue effects, severe noise exposures may also result in inner hair cell death and loss of auditory nerve fibers (Henderson et al., 2006).

The relationship between TTS and PTS is complicated and poorly understood, even in humans and terrestrial mammals, where numerous studies failed to delineate a clear relationship between the two. Relatively small amounts of TTS (e.g., less than 40–50 dB measured two minutes after exposure) will recover with no apparent permanent effects; however, terrestrial mammal studies revealed that larger amounts of threshold shift can result in permanent neural degeneration, despite the hearing thresholds returning to normal (Kujawa & Liberman, 2009). The amounts of threshold shift induced by Kujawa and Liberman (2009) were described as being "at the limits of reversibility." It is unknown whether smaller amounts of threshold shift can result in similar neural degeneration, or if effects would translate to other species such as marine animals.

Hearing loss can increase an animal’s physiological stress (Box B8), which feeds into the stress response (Box B7). Hearing loss increases the likelihood or severity of a behavioral response and increase an animal's overall physiological stress level (Box D10). Hearing loss reduces the distance over which animals can communicate and detect other biologically important sounds (Box D3). Hearing loss could also be inconsequential for an animal if the frequency range affected is not critical for that animal to hear within, or the hearing loss is of such short duration (e.g., a few minutes) that there are no costs to the individual.

Small to moderate amounts of hearing loss may recover over a period of minutes to days, depending on the amount of initial threshold shift. Severe noise-induced hearing loss may not fully recover, resulting in some amount of PTS. An animal whose hearing does not recover quickly and fully could suffer a reduction in lifetime reproductive success. An animal with PTS may be less successful at mating for one or more breeding seasons, thereby decreasing the number of offspring it can produce over its lifetime.

3.0.3.6.1.3 Masking

Masking occurs if the noise from an activity interferes with an animal’s ability to detect, understand, or recognize biologically relevant sounds of interest (Box B4). In this context noise refers to unwanted or unimportant sounds that mask an animal’s ability to hear sounds of interest. Sounds of interest include those from conspecifics such as offspring, mates, and competitors; echolocation clicks; sounds from predators; natural, abiotic sounds that may aid in navigation; and reverberation, which can give an animal information about its location and orientation within the ocean. The probability of masking increases as the noise and sound of interest increase in similarity and the masking noise increases in level. The frequency, received level, and duty cycle of the noise determines the potential degree of auditory masking. Masking only occurs during the sound exposure.

A behavior decision (either conscious or instinctive) is made by the animal when the animal detects increased background noise, or possibly, when the animal recognizes that biologically relevant sounds are being masked (Box C1). An animal’s past experiences can be important in determining the behavioral response when dealing with masking (Box C4). For example, an animal may modify its vocalizations to reduce the effects of masking noise. Other stimuli present in the environment can influence an animal’s behavior decision (Box C5) such as the presence of predators, prey, or potential mates.

An animal may exhibit a passive behavioral response when coping with masking (Box C2). It may simply not respond and keep conducting its current natural behavior. An animal may also stop calling until the background noise decreases. These passive responses do not present a direct energetic cost to the animal; however, masking will continue, depending on the acoustic stimuli.

An animal may actively compensate for masking (Box C3). An animal can vocalize more loudly to make its signal heard over the masking noise. An animal may also shift the frequency of its vocalizations away from the frequency of the masking noise. This shift can actually reduce the masking effect for the animal and other animals that are listening in the area.

If masking impairs an animal’s ability to hear biologically important sounds (Box D3) it could reduce an animal's ability to communicate with conspecifics or reduce opportunities to detect or attract more distant mates, gain information about their physical environment, or navigate. An animal that modifies its vocalization in response to masking could also incur a cost (Box D4). Modifying vocalizations may cost the animal energy, interfere with the behavioral function of a call, or reduce a signaler’s apparent quality as a mating partner. For example, songbirds that shift their calls up an octave to compensate for increased background noise attract fewer or less-desirable mates, and many terrestrial species advertise body size and quality with low-frequency vocalizations (Slabbekoorn & Ripmeester, 2007). Masking may also lead to no measurable costs for an animal. Masking could be of short duration or intermittent such that biologically important sounds that are continuous or repeated are received by the animal between masking noise.

Masking only occurs when the sound source is operating; therefore, direct masking effects stop immediately upon cessation of the sound-producing activity. Masking could have long-term consequences for individuals if the activity was continuous or occurred frequently enough.

3.0.3.6.1.4 Physiological Stress

Marine animals naturally experience physiological stress as part of their normal life histories. The physiological response to a stressor, often termed the stress response, is an adaptive process that helps an animal cope with changing external and internal environmental conditions. Sound-producing activities have the potential to cause additional stress. However, too much of a stress response can be harmful to an animal, resulting in physiological dysfunction.

If a sound is detected (i.e., heard or sensed) by an animal, a stress response can occur (Box B7). The severity of the stress response depends on the received sound level by the animal (Box A2), the details of the sound-producing activity (Box A1), and the animal's life history stage (e.g., juvenile or adult, breeding or feeding season), and past experience with the stimuli (Box B5). An animal's life history stage is an important factor to consider when predicting whether a stress response is likely (Box B5). An animal's life history stage includes its level of physical maturity (i.e., larva, infant, juvenile, sexually mature adult) and the primary activity in which it is engaged such as mating, feeding, or rearing/caring for young. Prior experience with a stressor may be of particular importance because repeated experience with a stressor may dull the stress response via acclimation (St. Aubin & Dierauf, 2001) or increase the response via sensitization. Additionally, if an animal suffers injury or hearing loss, a physiological stress response will occur (Box B8).

The generalized stress response is characterized by a release of hormones (Reeder & Kramer, 2005) and other chemicals (e.g., stress markers) such as reactive oxidative compounds associated with noise-induced hearing loss (Henderson et al., 2006). Stress hormones include norepinephrine and epinephrine (i.e., the catecholamines), which produce elevations in the heart and respiration rate, increase awareness, and increase the availability of glucose and lipid for energy. Other stress hormones are the glucocorticoid steroid hormones cortisol and aldosterone, which are classically used as an indicator of a stress response and to characterize the magnitude of the stress response (Hennessy et al., 1979).

An acute stress response is traditionally considered part of the startle response and is hormonally characterized by the release of the catecholamines. Annoyance type reactions may be characterized by the release of either or both catecholamines and glucocorticoid hormones. Regardless of the physiological changes that make up the stress response, the stress response may contribute to an animal's decision to alter its behavior.

Elevated stress levels may occur whether or not an animal exhibits a behavioral response (Box D10). Even while undergoing a stress response, competing stimuli (e.g., food or mating opportunities) may overcome any behavioral response. Regardless of whether the animal displays a behavioral response, this tolerated stress could incur a cost to the animal. Reactive oxygen compounds produced during normal physiological processes are generally counterbalanced by enzymes and antioxidants; however, excess stress can lead to damage of lipids, proteins, and nucleic acids at the cellular level (Berlett & Stadtman, 1997; Sies, 1997; Touyz, 2004).

Frequent physiological stress responses may accumulate over time increasing an animal's chronic stress level. Each component of the stress response is variable in time, and stress hormones return to baseline levels at different rates. Elevated chronic stress levels are usually a result of a prolonged or repeated disturbance. Chronic elevations in the stress levels (e.g., cortisol levels) may produce long-term health consequences that can reduce lifetime reproductive success.

3.0.3.6.1.5 Behavioral Reactions

Behavioral responses fall into two major categories: alterations in natural behavior patterns and avoidance. These types of reactions are not mutually exclusive, and many overall reactions may be combinations of behaviors or a sequence of behaviors. Severity of behavioral reactions can vary drastically between minor and brief reorientations of the animal to investigate the sound, to severe reactions such as aggression or prolonged flight. The type and severity of the behavioral response will determine the cost to the animal. The total number of vessels and platforms involved, the size of the activity area, the distance between the animal and activity, and the duration of the activity are important considerations when predicting the initial behavioral responses.

A physiological stress response (Box B7) such as an annoyance or startle reaction, or cueing or alerting (Box B6) may cause an animal to make a behavior decision (Box C6). Any exposure that produces an injury or hearing loss is also assumed to produce a stress response (Box B7) and increase the severity or likelihood of a behavioral reaction. Both an animal's experience (Box C4) and competing and reinforcing stimuli (Box C5) can affect an animal's behavior decision. The decision can result in three general types of behavioral reactions: no response (Box C9), area avoidance (Box C8), or alteration of a natural behavior (Box C7).

An animal's past experiences can be important in determining what behavior decision it may make when dealing with a stress response (Box C4). Habituation is the process by which an animal learns to ignore or tolerate stimuli over some period and return to a normal behavior pattern, perhaps after being exposed to the stimuli with no negative consequences. Sensitization is when an animal becomes more sensitive to a set of stimuli over time, perhaps as a result of a past, negative experience that could result in a stronger behavioral response.

Other stimuli (Box C5) present in the environment can influence an animal's behavioral response. These stimuli may be conspecifics or predators in the area or the drive to engage in a natural behavior. Other stimuli can also reinforce the behavioral response caused by acoustic stimuli. For example, the awareness of a predator in the area coupled with the sound-producing activity may elicit a stronger reaction than the activity alone would have.

An animal may reorient, become more vigilant, or investigate if it detects a sound-producing activity (Box C7). These behaviors all require the animal to divert attention and resources, therefore slowing or stopping their presumably beneficial natural behavior. This can be a very brief diversion, or an animal may not resume its natural behaviors until after the activity has concluded. An animal may choose to leave or avoid an area where a sound-producing activity is taking place (Box C8). A more severe form of this comes in the form of flight or evasion. Avoidance of an area can help the animal avoid further effects by avoiding or reducing further exposure. An animal may also choose not to respond to a sound-producing activity (Box C9).

An animal that alters its natural behavior in response to stress or an auditory cue may slow or cease its natural behavior and instead expend energy reacting to the sound-producing activity (Box D5). Natural behaviors include feeding, breeding, sheltering, and migrating. The cost of feeding disruptions depends on the energetic requirements of individuals and the potential amount of food missed during the disruption. Alteration in breeding behavior can result in delaying reproduction. The costs of a brief interruption to migrating or sheltering are less clear.

An animal that avoids a sound-producing activity may expend additional energy moving around the area, be displaced to poorer resources, miss potential mates, or have social interactions affected (Box D6). The amount of energy expended depends on the severity of the behavioral response. Missing potential mates can result in delaying reproduction. Groups could be separated during a severe behavioral response such as flight and offspring that depend on their parents may die if they are permanently separated. Splitting up an animal group can result in a reduced group size, which can have secondary effects on individual foraging success and susceptibility to predators.

Some severe behavioral reactions can lead to stranding (Box D7) or secondary injury (Box D8). Animals that take prolonged flight, a severe avoidance reaction, may injure themselves or strand in an environment for which they are not adapted. Some injury is likely to occur to an animal that strands (Box D8). Injury can reduce the animal's ability to secure food and mates, and increase the animal's susceptibility to predation and disease (Box D2). An animal that strands and does not return to a hospitable environment may die (Box D9).

3.0.3.6.1.6 Long-Term Consequences

The potential long-term consequences from behavioral responses are difficult to discern. Animals displaced from their normal habitat due to an avoidance reaction may return over time and resume their natural behaviors. This is likely to depend upon the severity of the reaction and how often the activity is repeated in the area. In areas of repeated and frequent acoustic disturbance, some animals may habituate to the new baseline; conversely, species that are more sensitive may not return, or return but not resume use of the habitat in the same manner. For example, an animal may return to an area to feed but no longer rest in that area. Long-term abandonment or a change in the utilization of an area by enough individuals can change the distribution of the population. Frequent disruptions to natural behavior patterns may not allow an animal to recover between exposures, which increase the probability of causing long-term consequences to individuals.

The magnitude and type of effect and the speed and completeness of recovery (i.e., return to baseline conditions) must be considered in predicting long-term consequences to the individual animal (Box E4). The predicted recovery of the animal (Box E1) is based on the cost to the animal from any reactions, behavioral or physiological. Available resources fluctuate by season, location, and year and can play a major role in an animal's rate of recovery (Box E2). Recovery can occur more quickly if plentiful food resources, many potential mates, or refuge or shelter is available. An animal's health, energy reserves, size, life history stage, and resource gathering strategy affect its speed and completeness of recovery (Box E3). Animals that are in good health and have abundant energy reserves before an effect takes place will likely recover more quickly.

Animals that recover quickly and completely are unlikely to suffer reductions in their health or reproductive success, or experience changes in habitat utilization (Box F2). No population-level effects would be expected if individual animals do not suffer reductions in their lifetime reproductive success or change their habitat utilization (Box G2). Animals that do not recover quickly and fully could suffer reductions in their health and lifetime reproductive success; they could be permanently displaced or change how they use the environment; or they could die (Box F1). These long-term consequences to the individual can lead to consequences for the population (Box G1); although, population dynamics and abundance play a role in determining how many individuals would need to suffer long-term consequences before there was an effect on the population.

Long-term consequences to individuals can translate into consequences for populations dependent upon population abundance, structure, growth rate, and carry capacity. Carrying capacity describes the theoretical maximum number of animals of a particular species that the environment can support. When a population nears its carrying capacity, its growth is naturally limited by available resources and predator pressure. If one, or a few animals, in a population are removed or gather fewer resources, then other animals in the population can take advantage of the freed resources and potentially increase their health and lifetime reproductive success. Abundant populations that are near their carrying capacity (theoretical maximum abundance) that suffer consequences on a few individuals may not be affected overall. Populations that exist well below their carrying capacity may suffer greater consequences from any lasting consequences to even a few individuals. Population-level consequences can include a change in the population dynamics, a decrease in the growth rate, or a change in geographic distribution.

3.0.3.6.2 Conceptual Framework for Assessing Effects from Energy-Producing Activities

3.0.3.6.2.1 Stimuli

Magnitude of the Energy Stressor

Regulations do not provide threshold criteria to determine the significance of the potential effects from activities that involve the use of varying electromagnetic frequencies or lasers. Many organisms, primarily marine vertebrates, have been studied to determine their thresholds for detecting electromagnetic fields, as reviewed by Normandeau et al. (2011); however, there are no data on predictable responses to exposure above or below detection thresholds. The types of electromagnetic fields discussed are those from mine neutralization activities (magnetic influence minesweeping). High-energy and low-energy lasers were considered for analysis. Low-energy lasers (e.g., targeting systems, detection systems, laser light detection and ranging) do not pose a risk to organisms (U.S. Department of the Navy, 2010) and, therefore, will not be discussed further. Radar was also considered for analysis and was determined not to pose a risk to biological resources.

Location of the Energy Stressor

Evaluation of potential energy exposure risks considered the spatial overlap of the resource occurrence and electromagnetic field and high-energy laser use. Wherever appropriate, specific geographic areas of potential impact were identified and the relative location of the resource with respect to the source was considered. For example, the greatest potential electromagnetic energy exposure is at the source, where intensity is greatest and the greatest potential for high energy laser exposure is at the ocean's surface, where high-energy laser intensity is greatest. All light energy, including laser light, entering the ocean becomes absorbed and scattered at a rate that is dependent on the frequency of the light. For most laser applications, the energy is rapidly reduced as the light penetrates the ocean.

Behavior of the Organism

Evaluation of potential energy exposure risk considered the behavior of the organism, especially where the organism lives and feeds (e.g., surface, water column, seafloor). The analysis for electromagnetic devices considered those species with the ability to perceive or detect electromagnetic signals. The analysis for high-energy lasers and radar particularly considered those species known to occur at or above the surface of the ocean.

3.0.3.6.2.2 Immediate Response and Costs to the Individual

Many different types of organisms (e.g., some invertebrates, fishes, turtles, birds, mammals) are sensitive to electromagnetic fields (Normandeau et al., 2011). An organism that encounters a disturbance in an electromagnetic field could respond by moving toward the source, moving away from it, or not responding at all. The types of electromagnetic devices used in the Proposed Action simulate the electromagnetic signature of a vessel passing through the water column, so the expected response would be similar to that of vessel movement. However, since there would be no actual strike potential, a physiological response would be unlikely in most cases. Recovery of an individual from encountering electromagnetic fields would be variable, but since the physiological response would likely be minimal, as reviewed by Normandeau et al. (2011), any recovery time would also be minimal.

Very little data are available to analyze potential impacts on organisms from exposure to high energy lasers. For all but the highest-energy lasers, the greatest laser-related concern for marine species is damage to an organism’s ability to see.

3.0.3.6.2.3 Long-Term Consequences to the Individual and Population

Long-term consequences are considered in terms of a resource’s existing population level, growth and mortality rates, other stressors on the resource from the Proposed Action, cumulative impacts on the resource, and the ability of the population to recover from or adapt to impacts. Impacts of multiple or repeated stressors on individuals are cumulative.

3.0.3.6.3 Conceptual Framework for Assessing Effects from Physical Disturbance or Strike

3.0.3.6.3.1 Stimuli

<u>Size and Weight of the Objects</u>

To determine the likelihood of a strike and the potential impacts on an organism or habitat that would result from a physical strike, the size and weight of the striking object relative to the organism or habitat must be considered. For example, most small organisms and early life stages would simply be displaced by the movement generated by a large object moving through, or falling into, the water, whereas a larger organism could potentially be struck by an object since it may not be displaced by the movement of the water. The weight of the object is also a factor that would determine the severity of a strike. A strike by a heavy object would be more severe than a strike by a low-weight object (e.g., a decelerator/parachute, flare end cap, or chaff canister).

<u>Location and Speed of the Objects</u>

Evaluation of potential physical disturbance or strike risk considered the spatial overlap of the resource occurrence and potential striking objects. Analysis of impacts from physical disturbance or strike stressors focuses on proposed activities that may cause an organism or habitat to be struck by an object moving through the air (e.g., aircraft), water (e.g., vessels, in-water devices, towed devices), or dropped into the water (e.g., non-explosive practice munitions and seafloor devices). The area of operation, vertical distribution, and density of these items also play central roles in the likelihood of impact. Wherever appropriate, specific geographic areas of potential impact are identified. Analysis of potential physical disturbance or strike risk also considered the speed of vessels as a measure of intensity. Some vessels move slowly, while others are capable of high speeds.

Buoyancy of the Objects

Evaluation of potential physical disturbance or strike risk in the ocean considered the buoyancy of targets or expended materials during operation, which will determine whether the object will be encountered at the surface, within the water column, or on the seafloor.

Behavior of the Organism

Evaluation of potential physical disturbance or strike risk considered where organisms occur and if they occur in the same geographic area and vertical distribution as those objects that pose strike risks.

3.0.3.6.3.2 Immediate Response and Costs to the Individual

Before being struck, some organisms would sense a pressure wave through the water and respond by remaining in place, moving away from the object, or moving toward it. An organism displaced a small distance by movements from an object falling into the water nearby would likely continue on with no response. However, others could be disturbed and may exhibit a generalized stress response. If the object actually hit the organism, direct injury in addition to stress may result. The function of the stress response in vertebrates is to rapidly raise the blood sugar level to prepare the organism to flee or fight. This generally adaptive physiological response can become a liability if the stressor persists and the organism cannot return to its baseline physiological state.

Most organisms would respond to sudden physical approach or contact by darting quickly away from the stimulus. Other species may respond by freezing in place or seeking refuge. In any case, the individual must stop whatever it was doing and divert its physiological and cognitive attention to responding to the stressor. The energy costs of reacting to a stressor depend on the specific situation, but in all cases the caloric requirements of stress reactions reduce the amount of energy available to the individual for other functions such as predator avoidance, reproduction, growth, and metabolism.

The ability of an organism to return to what it was doing following a physical strike (or near miss resulting in a stress response) is a function of fitness, genetic, and environmental factors. Some organisms are more tolerant of environmental or human-caused stressors than others and become acclimated more easily. Within a species, the rate at which an individual recovers from a physical disturbance or strike may be influenced by its age, sex, reproductive state, and general condition. An organism that has reacted to a sudden disturbance by swimming at burst speed would tire after some time; its blood hormone and sugar levels may not return to normal for 24 hours. During the recovery period, the organism may not be able to attain burst speeds and could be more vulnerable to predators. If the individual were not able to regain a steady state following exposure to a physical stressor, it may suffer depressed immune function and even death.

3.0.3.6.3.3 Long-Term Consequences to the Population

Long-term consequences are considered in terms of a resource's existing population level, growth and mortality rates, other stressors on the resource from the Proposed Action, cumulative impacts on the resource, and the ability of the population to recover from or adapt to impacts. Impacts of multiple or repeated stressors on individuals are cumulative.

3.0.3.6.4 Conceptual Framework for Assessing Effects from Entanglement

3.0.3.6.4.1 Stimuli

Physical Properties of the Objects

For an organism to become entangled in military expended materials, the materials must have certain properties, such as the ability to form loops and a high breaking strength. Some items could have a relatively low breaking strength on their own, but that breaking strength could be increased if multiple loops were wrapped around an entangled organism.

Physical Features of the Resource

The physical makeup of the organism itself is also considered when evaluating the risk of entanglement. Some species, by their size or physical features, are more susceptible to entanglement than others. For example, more rigid bodies with protruding snouts (e.g., hammerhead shark) or large, rigid fins (e.g., humpback whale) would have an increased risk of entanglement when compared to species with smoother, streamlined bodies such as lamprey or eels.

Location of the Objects

Evaluation of potential entanglement risk considered the spatial overlap of the resource occurrence and military expended materials. Distribution and density of expended items play a central role in the likelihood of impact. Wherever appropriate, specific geographic areas of potential impact are identified.

Buoyancy of Objects

Evaluation of potential entanglement risk considered the buoyancy of military expended materials to determine whether the object will be encountered within the water column (including the surface) or on the seafloor. Less buoyant materials, such as torpedo guidance wires, sink rapidly to the seafloor. More buoyant materials include less dense items (e.g., decelerators/parachutes) that are weighted and would sink slowly to the seafloor and could be entrained in currents.

Behavior of the Organism

Evaluation of potential entanglement risk considered the general behavior of the organism, including where the organism typically occurs (e.g., surface, water column, seafloor). The analysis particularly considered those species known to become entangled in nonmilitary expended materials (e.g., "marine debris") such as fishing lines, nets, rope, and other derelict fishing gear that often entangle marine organisms.

3.0.3.6.4.2 Immediate Response and Costs to the Individual

The potential impacts of entanglement on a given organism depend on the species and size of the organism. Species that have protruding snouts, fins, or appendages are more likely to become entangled than smooth-bodied organisms. Also, items could get entangled by an organism's mouth, if caught on teeth or baleen, with the rest of the item trailing alongside the organism. Materials similar to fishing gear, which is designed to entangle an organism, would be expected to have a greater entanglement potential than other materials. An entangled organism would likely try to free itself of the entangling object and in the process may become even more entangled, possibly leading to a stress response. The net result of being entangled by an object could be disruption of the normal behavior, injury due to lacerations, and other sublethal or lethal impacts.

3.0.3.6.4.3 Long-Term Consequences to the Individual and Population

Consequences of entanglement could range from an organism successfully freeing itself from the object or remaining entangled indefinitely, possibly resulting in lacerations and other sublethal or lethal impacts. Stress responses or infection from lacerations could lead to latent mortality. The analysis will focus on reasonably foreseeable long-term consequences of the direct impact, particularly those that could impact the fitness of an individual. Changes in an individual's growth, survival, annual reproductive success, or lifetime reproductive success could have population-level impacts if enough individuals are impacted. This population-level impact would vary among species and taxonomic groups.

3.0.3.6.5 Conceptual Framework for Assessing Effects from Ingestion

3.0.3.6.5.1 Stimuli

Size of the Objects

To assess the ingestion risk from military expended materials, this analysis considered the size of the object relative to the animal's ability to swallow it. Some items are too large to be ingested (e.g., non-explosive practice bombs and most targets) and impacts from these items are not discussed further. However, these items may potentially break down into smaller ingestible pieces over time. Items that are of ingestible size when they are introduced into the environment are carried forward for analysis within each resource section where applicable.

Location of the Objects

Evaluation of potential ingestion risk considered the spatial overlap of the resource occurrence and military expended materials. The distribution and density of expended items play a central role in the likelihood of impact. Wherever appropriate, specific geographic areas of potential impact were identified.

Buoyancy of the Objects

Evaluation of potential ingestion risk considered the buoyancy of military expended materials to determine whether the object will be encountered within the water column (including the surface) or on the seafloor. Less buoyant materials, such as solid metal materials (e.g., projectiles or munitions fragments), sink rapidly to the seafloor. More buoyant materials include less dense items (e.g., target fragments and decelerators/parachutes) that may be caught in currents and gyres or entangled in floating kelp. These materials can remain in the water column for an indefinite period of time before sinking. However, decelerators/parachutes are weighted and would generally sink, unless that sinking is suspended, in the scenario described here.

Feeding Behavior

Evaluation of potential ingestion risk considered the feeding behavior of the organism, including where (e.g., surface, water column, seafloor) and how (e.g., filter feeding) the organism feeds and what it feeds on. The analysis particularly considered those species known to ingest nonfood items (e.g., plastic or metal items).

3.0.3.6.5.2 Immediate Response and Costs to the Individual

Potential impacts of ingesting foreign objects on a given organism depend on the species and size of the organism. Species that normally eat spiny hard-bodied invertebrates would be expected to have tougher mouths and guts than those that normally feed on softer prey. Materials similar in size and shape to the normal diet of an organism may be more likely to be ingested without causing harm to the animal;

however, some general assumptions were made. Relatively small objects with smooth edges, such as shells or small-caliber projectiles, might pass through the digestive tract without causing harm. A small sharp-edged item may cause the individual immediate physical distress by tearing or cutting the mouth, throat, or stomach. If the object is rigid and large (relative to the individual's mouth and throat), it may block the throat or obstruct digestive processes. An object may even be enclosed by a cyst in the gut lining. The net result of ingesting large foreign objects is disruption of the normal feeding behavior, which could be sublethal or lethal.

3.0.3.6.5.3 Long-Term Consequences to the Individual and Population

The consequences of ingesting nonfood items could be nutrient deficiency, bioaccumulation, uptake of toxic chemicals, compaction, and mortality. The analysis focused on reasonably foreseeable long-term consequences of the direct impact, particularly those that could impact the fitness of an individual. Changes in an individual's growth, survival, annual reproductive success, or lifetime reproductive success could have population-level impacts if enough individuals were impacted. This population-level impact would vary among species and taxonomic groups.

3.0.3.6.6 Conceptual Framework for Assessing Effects from Secondary Stressors

This conceptual framework describes the potential effects to marine species exposed to stressors indirectly through impacts on habitat and prey availability (e.g., sediment or water quality, and physical disturbance). Stressors from Navy training and testing activities could pose indirect impacts on marine biological resources via indirect effects to habitat or to prey. These include indirect impacts from (1) explosives, explosion byproducts, and unexploded munitions; (2) metals; (3) chemicals; and (4) transmission of disease and parasites. The methods used to determine secondary stressors on marine resources are presented below. Once a category of primary stressor has been analyzed to determine how a marine biological resource is impacted, an analysis follows of how a secondary stressor is potentially impacting a marine resource. After the secondary stressors are identified, a determination on the significance of the secondary impact is made. The same criteria to determine the level of significance for primary impacts are used for secondary stressors. In addition, it is possible for a significant primary impact to produce a beneficial indirect impact. For example, sinking exercises could generate a significant impact to the seafloor and surrounding habitats, while causing a potential beneficial secondary impact by creating hard-bottom habitat for invertebrates, producing a food source for fishes, and creating structural refuges for other biological resources.

3.0.3.6.6.1 Secondary Stressors

<u>Impacts on Habitat</u>

Primary impacts defined in each marine resource section were used to develop a conceptual model to predict the potential secondary stressors on each habitat or resource. This conceptual model incorporated factors such as the co-occurrence of stressors in space and time, the impacts or assessment endpoints of individual stressors (e.g., habitat alteration, changes in animal behavior or physiology, injury, mortality, or changes in human use), and the duration and intensity of the impacts of individual stressors. For example, a secondary stressor from a munitions strike could be habitat degradation. The primary impact or stressor is the actual strike on the habitat such as the seafloor, with the introduction of military expended materials, munitions, and fragments inducing further habitat degradation.

Secondary stressors can also induce additive impacts on habitats. These types of impacts are also determined by summing the individual stressors with identical and quantifiable assessment endpoints.

For example, if one stressor disturbed 0.25 NM^2 of benthic habitat, a second stressor disturbed 0.5 NM^2, and all other stressors did not disturb benthic habitat, then the total benthic habitat disturbed would be 0.75 NM^2. For stressors with identical but not quantifiable assessment endpoints, potential additive impacts were qualitatively evaluated using available scientific knowledge and best professional judgment. Other habitat impacts such as underwater detonations were assessed by size of charge (net explosive weight), charge radius, height above the seafloor, substrate types in the area, and equations linking all these factors. The analysis also considered that impacts of underwater explosions vary with the bottom substrate type and that the secondary impacts would also be variable among substrate types.

Impacts on Prey Availability

Assessing the impacts of secondary stressors on prey availability falls into two main areas over different temporal scales: the cost to an individual over a relatively short amount of time (short-term) and the cost to an individual or population over a longer period of time (long-term).

3.0.3.6.6.2 Immediate Response and Costs to the Individual

After a primary impact was identified, an analysis of secondary stressors on that resource was initiated. This analysis examined whether indirect impacts would occur after the initial (primary) impact and at what temporal scale that secondary stressor would affect the resource (short-term or long-term). An assessment was then made as to whether the secondary stressor would impact an individual or a population. For example, an underwater explosion could impact a single resource such as a fish or multiple other species in the food web (e.g., prey species such as plankton). The analysis also took into consideration whether the primary impact affected more than an individual or single species. For example, a prey species that would be directly injured or killed by an explosive blast could draw in predators or scavengers from the surrounding waters that would feed on those organisms, and in turn could be more directly susceptible to being injured or killed by subsequent explosions. For purposes of this analysis, indirect impacts on a resource did not require trophic transfer (e.g., bioaccumulation) in order to be observed. It is important to note that the terms “indirect” and “secondary” describe how the impact may occur in an organism or its ecosystem and does not imply reduced severity of environmental consequences.

3.0.3.6.6.3 Long-Term Consequences to the Individual and Population

Long-term consequences of secondary stressors on an individual or population are often difficult to determine. Once a primary impact is identified, the severity of that impact helps to determine the temporal scale at which the secondary stressor can be measured. For most marine resources, the abundance of prey species near a detonation point would be diminished for a short period (weeks to months) before being repopulated by animals from adjacent waters. In some extreme cases, recovery of the habitat or prey resources could occur over a relatively long time frame (months to years). It is important to note that indirect impacts often differ among resources, spatial, and temporal scales.

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REFERENCES

Air Force Engineering and Services Center. (1981). *The Effect of Fuel Composition on Groundfall from Aircraft Fuel Jettisoning*. Tyndall Air Force Base, FL: Engineering and Services Laboratory.

Aquarone, M. C., and S. Adams. (2009a). *XIX-63 Insular Pacific-Hawaiian LME* (The UNEP Large Marine Ecosystem Report: A Perspective on Changing Conditions in LMEs of the World's Regional Seas). Nairobi, Kenya: United Nations Environmental Programme.

Aquarone, M. C., and S. Adams. (2009b). *XIV-44 California Current LME* (The UNEP Large Marine Ecosystem Report: A perspectiv on Changing Conditions in LMEs of the World's Regional Seas). Nairobi, Kenya: United Nations Environmental Programme.

Arfsten, D. P., C. L. Wilson, and B. J. Spargo. (2002). Radio frequency chaff: The effects of its use in training on the environment. *Ecotoxicology and Environmental Safety, 53*, 1–11.

Baird, R. (2013). Odontocete Cetaceans Around the Main Hawaiian Islands: Habitat Use and Relative Abundance from Small-Boat Sighting Surveys. *Aquatic Mammals, 39*(3), 253–269.

Baird, R. W., D. L. Webster, S. Watwood, R. Morrissey, B. K. Rone, S. D. Mahaffy, A. M. Gorgone, D. B. Anderson, and D. J. Moretti. (2016). *Odontocete Studies on the Pacific Missile Range Facility in February 2015: Satellite-Tagging, Photo-Identification, and Passive Acoustic Monitoring. Final Report*. Olympia, WA: HDR Environmental Inc.

Barlow, J. (2016). *Cetacean Abundance in the California Current Estimated from Ship-based Line-transect Surveys in 1991–2014.* (NOAA Administrative Report NMFS-SWFSC-LJ-1601). La Jolla, CA: Southwest Fisheries Science Center.

Batteen, M. L., N. J. Cipriano, and J. T. Monroe. (2003). A large-scale seasonal modeling study of the California current system. *Journal of Oceanography, 59*(5), 545–562.

Becker, E. A., K. A. Forney, P. C. Fiedler, J. Barlow, S. J. Chivers, C. A. Edwards, A. M. Moore, and J. V. Redfern. (2016). Moving Towards Dynamic Ocean Management: How Well Do Modeled Ocean Products Predict Species Distributions? *Remote Sensing, 8*(2), 149.

Bergmann, M., L. Gutow, and M. Klages. (2015). *Marine Anthropogenic Litter*. New York, NY and London, United Kingdom: Springer.

Berlett, B. S., and E. R. Stadtman. (1997). Protein oxidation in aging, disease, and oxidative stress. *The Journal of Biological Chemistry, 272*(33), 20313–20316.

Blanton, J., and J. G. Pattullo. (1970). The subsurface boundary between subarctic Pacific water and Pacific equatorial water in the transition zone off Southern California. *Limnology and Oceanography, 15*, 606–614.

Bograd, S. J., P. M. DiGiacomo, R. Durazo, T. L. Hayward, K. D. Hyrenbach, R. J. Lynn, A. W. Mantyla, F. B. Schwing, W. J. Sydeman, T. Baumgartner, B. Lavaniegos, and C. S. Moore. (2000). The state of the California current, 1999–2000: Forward to a new regime? *CalCOFI Report, 41*, 26–52.

Bograd, S. J. (2004). *California Current* (Marine Ecosystems of the North Pacific). Sidney, Canada: North Pacific Marine Science Organization.

Bost, C. A., C. Cotte, F. Bailleul, Y. Cherel, J. B. Charrassin, C. Guinet, D. G. Ainley, and H. Weimerskirch. (2009). The importance of oceanographic fronts to marine birds and mammals of the southern oceans. *Journal of Marine Systems, 78*, 363–376.

Bousman, W. G., and R. M. Kufeld. (2005). *UH-60A Airloads Catalog*. Moffett Field, CA: National Aeronautics and Space Administration.

Bradford, A. L., K. A. Forney, E. M. Oleson, and J. Barlow. (2017). Abundance estimates of cetaceans from a line-transect survey within the U.S. Hawaiian Islands Exclusive Economic Zone. *Fishery Bulletin, 115*(2), 129–142.

California Current Integrated Ecosystem Assessment Team. (2015). *State of the California Current Report, 2015*. Silver Spring, MD: National Oceanic and Atmospheric Administration Northwest, Southwest, and Alaska Fisheries Science Centers.

Campbell, G. S., L. Thomas, K. Whitaker, A. B. Douglas, J. Calambokidis, and J. A. Hildebrand. (2015). Inter-annual and seasonal trends in cetacean distribution, density and abundance off southern California. *Deep Sea Research Part II: Topical Studies in Oceanography, 112*, 143–157.

Carretta, J. V., E. Oleson, D. W. Weller, A. R. Lang, K. A. Forney, J. Baker, M. M. Muto, B. Hanson, A. J. Orr, H. Huber, M. S. Lowry, J. Barlow, J. Moore, D. Lynch, L. Carswell, and R. L. Brownell. (2015). *U.S. Pacific Marine Mammal Stock Assessments: 2014* (NOAA Technical Memorandum NMFS-SWFSC-549). La Jolla, CA: Southwest Fisheries Science Center.

Chavanne, C., P. Flament, R. Lumpkin, B. Dousset, and A. Bentamy. (2002). Scatterometer observations of wind variations induced by oceanic islands: Implications for wind-driven ocean circulation. *Canadian Journal of Remote Sensing, 28*(3), 466–474.

Chereskin, T. K., and P. P. Niiler. (1994). Circulation in the Ensenada Front - September 1988. *Deep-Sea Research I, 41*(8), 1251–1287.

Corning Incorporated. (2005). *Corning SMF-28e Optical Fiber Product Information*. Corning, NY: Corning Incorporated.

Courbis, S., and G. Timmel. (2008). Effects of vessels and swimmers on behavior of Hawaiian spinner dolphins (*Stenella longirostris*) in Kealake'akua, Honaunau, and Kauhako bays, Hawai'i. *Marine Mammal Science, 25*(2), 430–440.

Covault, J. A., W. R. Normark, B. W. Romans, and S. A. Graham. (2007). Highstand fans in the California borderland: The overlooked deep-water depositional system. *Geology, 35*(9), 783–786.

Crum, L., and Y. Mao. (1996). Acoustically enhanced bubble growth at low frequencies and its implications for human diver and marine mammal safety. *The Journal of the Acoustical Society of America, 99*(5), 2898–2907.

Crum, L., M. Bailey, J. Guan, P. Hilmo, S. Kargl, and T. Matula. (2005). Monitoring bubble growth in supersaturated blood and tissue *ex vivo* and the relevance to marine mammal bioeffects. *Acoustics Research Letters Online, 6*(3), 214–220.

Di Lorenzo, E. (2003). Seasonal dynamics of the surface circulation in the Southern California current system. *Deep-Sea Research II, 50*(14–16), 2371–2388.

Dickson, R. R., and J. Brown. (1994). The production of North Atlantic deep water: Sources, rates, and pathways. *Journal of Geophysical Research, 99*(C6), 12319–12341.

Dorman, C. E. (1982). Winds between San Diego and San Clemente island. *Journal of Geophysical Research, 87*(C12), 9636–9646.

Duda, A. M., and K. Sherman. (2002). A new imperative for improving management of large marine ecosystems. *Ocean & Coastal Management, 45*(11–12), 797–833.

Eller, A. I., and R. C. Cavanagh. (2000). *Subsonic Aircraft Noise at and Beneath the Ocean Surface: Estimation of Risk for Effects on Marine Mammals*. McLean, VA: United States Air Force Research Laboratory.

Environmental Sciences Group. (2005). *Canadian Forces Maritime Experimental and Test Ranges: Environmental Assessment Update 2005*. Kingston, Canada: Environmental Sciences Group, Royal Military College.

Fahlman, A., P. L. Tyack, P. J. O. Miller, and P. H. Kvadsheim. (2014). How man-made interference might cause gas bubble emboli in deep diving whales. *Frontiers in Physiology, 5*(13), 1–6.

Flament, P., S. Kennan, R. Lumpkin, M. Sawyer, and E. D. Stroup. (2009). *Ocean Atlas of Hawaii*. Manoa, HI: School of Ocean and Earth Science and Technology, University of Hawaii.

Forney, K. A., E. A. Becker, D. G. Foley, J. Barlow, and E. M. Oleson. (2015). Habitat-based models of cetacean density and distribution in the central North Pacific. *Endangered Species Research, 27*, 1–20.

Frisk, G. V. (2012). Noiseonomics: The relationship between ambient noise levels in the sea and global economic trends. *Scientific Reports, 2*(437).

Garrison, T. (1998). Seawater chemistry. In T. Garrison (Ed.), *Oceanography: An Invitation to Marine Science* (3rd ed., pp. 138–153). Belmont, CA: Wadsworth Publishing Company.

Gay, P. S., and T. K. Chereskin. (2009). Mean structure and seasonal variability of the poleward undercurrent off Southern California. *Journal of Geophysical Research, 114*, C02007.

Gelpi, C. G., and K. E. Norris. (2008). Seasonal temperature dynamics of the upper ocean in the Southern California Bight. *Journal of Geophysical Research, 113*, C04034.

Gergis, J. L., and A. M. Fowler. (2009). A history of ENSO events since A.D. 1525: Implications for future climate change. *Climatic Change, 92*, 343–387.

Gorsline, D. S. (1992). The geological setting of Santa Monica and San Pedro basins, California continental borderland. *Progress in Oceanography, 30*(1–4), 1–36.

HDR. (2012). *Summary Report: Compilation of Visual Survey Effort and Sightings for Marine Species Monitoring in the Hawaii Range Complex, 2005–2012* (Prepared for Commander, U.S. Pacific Fleet, Pearl Harbor, Hawaii). San Diego, CA: HDR Inc.

Henderson, D., E. C. Bielefeld, K. C. Harris, and B. H. Hu. (2006). The role of oxidative stress in noise-induced hearing loss. *Ear & Hearing, 27*, 1–19.

Hennessy, M. B., J. P. Heybach, J. Vernikos, and S. Levine. (1979). Plasma corticosterone concentrations sensitively reflect levels of stimulus intensity in the rat. *Physiology and Behavior, 22*, 821–825.

Hickey, B. M. (1992). Circulation over the Santa Monica—San Pedro basin and shelf. *Progress in Oceanography, 30*(1–4), 37–115.

Hildebrand, J. (2009). Anthropogenic and natural sources of ambient noise in the ocean. *Marine Ecology Progress Series, 395*, 5–20.

Houser, D. S., L. A. Dankiewicz-Talmadge, T. K. Stockard, and P. J. Ponganis. (2009). Investigation of the potential for vascular bubble formation in a repetitively diving dolphin. *The Journal of Experimental Biology, 213*, 52–62.

Howell, E. A., P. H. Dutton, J. J. Polovina, H. Bailey, D. M. Parker, and G. H. Balazs. (2010). Oceanographic influences on the dive behavior of juvenile loggerhead turtles (*Caretta caretta*) in the north Pacific Ocean. *Marine Biology, 157*(5), 1011–1026.

Hunter, E., R. Chant, L. Bowers, S. Glenn, and J. Kohut. (2007). Spatial and temporal variability of diurnal wind forcing in the coastal ocean. *Geophysical Research Letters, 34*(3), L03607.

Illingworth and Rodkin, Inc. (2015). *Underwater and Airborne Acoustic Monitoring for the U.S. Navy Elevated Causeway Removal at the JEB Little Creek Naval Station: 10–11 September 2015* (Naval Facilities Engineering Command Atlantic under HDR Environmental, Operations and Construction, Inc.). Petaluma, CA: Illingworth & Rodkin, Inc.

Illingworth and Rodkin, Inc. (2017). *Pile-Driving Noise Measurements at Atlantic Fleet Naval Installations: 28 May 2013–28 April 2016. Final Report*. Petaluma, CA: HDR.

Itano, D. G., and K. N. Holland. (2000). Movement and vulnerability of bigeye (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*) in relation to FADs and natural aggregation points. *Aquatic Living Resources, 13*(4), 213–223.

Jefferson, T. A., M. A. Smultea, and C. E. Bacon. (2014). Southern California Bight marine mammal density and abundance from aerial survey, 2008–2013. *Journal of Marine Animals and Their Ecology, 7*(2), 14–30.

Johnson, G. C. (2008). Quantifying Antarctic bottom water and North Atlantic deep water volumes. *Journal of Geophysical Research, 113*, C05027.

Kawabe, M., and S. Fujito. (2010). Pacific Ocean circulation based on observation. *Journal of Oceanography, 66*, 389–403.

Kujawa, S. G., and M. C. Liberman. (2009). Adding insult to injury: Cochlear nerve degeneration after "temporary" noise-induced hearing loss. *The Journal of Neuroscience, 29*(45), 14077–14085.

Loh, A. N., and J. E. Bauer. (2000). Distribution, partitioning and fluxes of dissolved and particulate organic C, N and P in the eastern north Pacific and southern Oceans. *Deep-Sea Research I, 47*(12), 2287–2316.

Lynn, R. J., S. J. Bograd, T. K. Chereskin, and A. Huyer. (2003). Seasonal renewal of the California Current: The spring transition off California. *Journal of Geophysical Research, 108*(C8), 3279.

Madden, C. J., K. Goodin, R. J. Allee, G. Cicchetti, C. Moses, M. Finkbeiner, and D. Bamford. (2009). *Coastal and Marine Ecological Classification Standard—Version III*. Arlington, VA and Charleston, SC: National Oceanic and Atmospheric Administration and NatureServe.

Mantua, N. J., and S. R. Hare. (2002). The Pacific Decadal Oscillation. *Journal of Oceanography, 58*, 35–44.

McKenna, M. F., D. Ross, S. M. Wiggins, and J. A. Hildebrand. (2012). Underwater radiated noise from modern commercial ships. *The Journal of the Acoustical Society of America, 131*(1), 92–103.

McLennan, M. W. (1997). *A Simple Model for Water Impact Peak Pressure and Pulse Width: A Technical Memorandum*. Goleta, CA: Greeneridge Sciences, Inc.

Milstein, M. (2015). *Oncoming El Niño Likely to Continue Species Shakeup in Pacific*. Retrieved from http://www.nwfsc.noaa.gov/news/features/el_nino/index.cfm.

Mintz, J. D., and C. L. Parker. (2006). *Vessel Traffic and Speed Around the U.S. Coasts and Around Hawaii*. Alexandria, VA: CNA Corporation.

Mintz, J. D., and R. J. Filadelfo. (2011). *Exposure of Marine Mammals to Broadband Radiated Noise* (Specific Authority N0001-4-05-D-0500). Washington, DC: Center for Naval Analyses.

Mintz, J. D. (2012). *Vessel Traffic in the Hawaii-Southern California and Atlantic Fleet Testing and Training Study Areas*. (CRM D0026186.A2/Final). Alexandria, VA: Center for Naval Analyses.

Mintz, J. D. (2016). *Characterization of Vessel Traffic in the Vicinities of HRC, SOCAL, and the Navy Operating Areas off the U.S. East Coast*. Alexandria, VA: Center for Naval Analyses.

Moody, A. (2000). Analysis of plant species diversity with respect to island characteristics on the Channel Islands, California. *Journal of Biogeography, 27*(3), 711–723.

Mulsow, J., C. E. Schlundt, L. Brandt, and J. J. Finneran. (2015). Equal latency contours for bottlenose dolphins (*Tursiops truncatus*) and California sea lions (*Zalophus californianus*). *The Journal of the Acoustical Society of America, 138*(5), 2678.

National Marine Fisheries Service. (2008). *Biological Opinion for the 2008 Rim-of-the-Pacific Joint Training Exercises*. Silver Spring, MD: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources, Endangered Species Division.

National Marine Fisheries Service. (2018). *2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts*. Silver Spring, MD: National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources

National Research Council. (1990). *Monitoring Southern California's Coastal Waters*. Washington, DC: National Academy Press.

Norcross, B. L., S. M. McKinnell, M. Frandsen, D. L. Musgrave, and S. R. Sweet. (2003). Larval fishes in relation to water masses of the central north Pacific transitional areas, including the shelf break of west-central Alaska. *Journal of Oceanography, 59*(4), 445–460.

Normandeau, E., T. Tricas, and A. Gill. (2011). *Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species*. Camarillo, CA: U.S. Department of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific Outer Continental Shelf Region.

North Pacific Marine Science Organization. (2004). *Marine Ecosystems of the North Pacific*. (PICES Special Publication 1). Sidney, British Columbia: North Pacific Marine Science Organization. Retrieved from http://www.pices.int/publications/special_publications/NPESR/2005/npesr_2005.aspx.

Pickard, G. L., and W. J. Emery. (1990). *Descriptive Physical Oceanography: An Introduction* (5th ed.). Oxford, UK: Pergamon Press.

Polovina, J. J., G. T. Mitchum, N. E. Graham, M. P. Craig, E. E. DeMartini, and E. N. Flint. (1994). Physical and biological consequences of a climate event in the central north Pacific. *Fisheries Oceanography, 3*(1), 15–21.

Polovina, J. J., W. R. Haight, R. B. Moffitt, and F. A. Parrish. (1995). The role of benthic habitat, oceanography, and fishing on the population dynamics of the spiny lobster, *Panulirus marginatus* (Decapoda, Palinuridae), in the Hawaiian archipelago. *Crustaceana, 68*(2), 203–212.

Polovina, J. J., E. Howell, D. R. Kobayashi, and M. P. Seki. (2001). The transition zone chlorophyll front, a dynamic global feature defining migration and forage habitat for marine resources. *Progress in Oceanography, 49*, 469–483.

Popper, A. N., A. D. Hawkins, R. R. Fay, D. A. Mann, S. M. Bartol, T. J. Carlson, S. Coombs, W. T. Ellison, R. L. Gentry, M. B. Halvorsen, S. Løkkeborg, P. H. Rogers, B. L. Southall, D. G. Zeddies, and W. N. Tavolga. (2014). *ASA S3/SC1.4 TR-2014 Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI*. New York, NY and London, United Kingdom: Acoustical Society of America Press and Springer Briefs in Oceanography.

Purdy, R. (2016). Kauai’s first documented green sea turtle nest of 2016 hatches: Sixty-three hatchlings emerge from Pacific Missile Range Facility. *Currents*(Fall), 24–25.

Qiu, B., D. A. Koh, C. Lumpkin, and P. Flament. (1997). Existence and formation mechanism of the North Hawaiian Ridge Current. *Journal of Physical Oceanography, 27*(3), 431–444.

Raytheon Company. (2015). *Airborne Mine Neutralization System (AMNS): Alternative Optical Fiber Engineering Study Final Report*. Portsmouth, RI: Integrated Defense Systems.

Reeder, D. M., and K. M. Kramer. (2005). Stress in free-ranging mammals: Integrating physiology, ecology, and natural history. *Journal of Mammalogy, 86*(2), 225–235.

Reid, J. L., Jr., G. I. Roden, and J. G. Wyllie. (1958). *Studies of the California Current system* (Progress Report, 1 July 1956 to 1 January 1958). La Jolla, CA: Scripps Institution of Oceanography.

Reinhall, P. G., and P. H. Dahl. (2011). Underwater Mach wave radiation from impact pile driving: Theory and observation. *The Journal of the Acoustical Society of America, 130*(3), 1209–1216.

Reverdin, G., P. P. Niiler, and H. Valdimarsson. (2003). North Atlantic Ocean Surface Currents. *Journal of Geophysical Research, 108*(C1), 3002.

Richardson, W. J., C. R. Greene, Jr., C. I. Malme, and D. H. Thomson. (1995). *Marine Mammals and Noise*. San Diego, CA: Academic Press.

Rooney, J., P. Wessel, R. Hoeke, J. Weiss, J. Baker, F. Parrish, C. H. Fletcher, J. Chojnacki, M. Garcia, R. Brainard, and P. Vroom. (2008). Geology and geomorphology of coral reefs in the northwestern Hawaiian islands. In B. M. Riegl & R. E. Dodge (Eds.), *Coral Reefs of the U.S.A. Coral Reefs of the World* (Vol. 1, pp. 515–567). New York, NY: Springer.

Santamaria-del-Angel, E., R. Millan-Nuñez, A. Gonzalez-Silvera, and F. Muller-Karger. (2002). The color signature of the Ensenada Front and its seasonal and interannual variability. *CalCOFI Report, 43*, 155–161.

Sies, H. (1997). Physiological Society Symposium: Impaired Endothelial and Smooth Muscle Cell Function in Oxidative Stress-Oxidative Stress: Oxidants and Antioxidants. *Experimental Physiology, 82*, 291–295.

Slabbekoorn, H., and E. A. Ripmeester. (2007). Birdsong and anthropogenic noise: Implications and applications for conservation. *Molecular Ecology, 17*(1), 72–83.

Sohn, R. A., F. Vernon, J. A. Hildebrand, and S. C. Webb. (2000). Field measurements of sonic boom penetration into the ocean. *The Journal of the Acoustical Society of America, 107*(6), 3073–3083.

Spargo, B. J. (2007). [Personal Communication with Mark Collins Regarding Chaff End Cap and Piston Bouyancy].

Sparrow, V. W. (2002). Review and status of sonic boom penetration into the ocean. *The Journal of the Acoustical Society of America, 111*(1), 537–543.

St. Aubin, D., and L. A. Dierauf. (2001). Stress and Marine Mammals. In L. A. Dierauf & F. M. D. Gulland (Eds.), *Marine Mammal Medicine* (2nd ed., pp. 253–269). Boca Raton, FL: CRC Press.

Swope, B., and J. McDonald. (2013). *Copper-Based Torpedo Guidance Wire: Applications and Environmental Considerations*. San Diego, CA: Space and Naval Warfare Systems Command Center Pacific.

Talley, L. D. (1993). Distribution and formation of north Pacific intermediate water. *Journal of Physical Oceanography, 23*(3), 517–537.

The White House Council on Environmental Quality. (2010). *Final Recommendations of the Interagency Ocean Policy Task Force*. Washington, DC: Executive Office of the President of the United States.

Tomczak, M., and J. S. Godfrey. (2003). The Pacific Ocean. In *Regional Oceanography: An Introduction* (2nd ed., pp. 105–174). Delhi, India: Daya Publishing House.

Touyz, R. M. (2004). Reactive oxygen species, vascular oxidative stress, and redox signaling in hypertension: What is the clinical significance? *Hypertension, 44*, 248–252.

U.S. Department of the Air Force. (1997). *Environmental Effects of Self-Protection Chaff and Flares*. Langley Air Force Base, VA: U.S. Air Force, Headquarters Air Combat Command.

U.S. Department of the Air Force. (2000). *Supersonic Aircraft Noise At and Beneath the Ocean Surface: Estimation of Risk for Effects on Marine Mammals* (AFRL-HE-WP-TR-2000-0167). McLean, VA: United States Air Force Research Laboratory.

U.S. Department of the Air Force. (2016). *United States Air Force F-35A Operational Beddown–Pacific Final Environmental Impact Statement*. Eielson AFB, AK: United States Air Force.

U.S. Department of the Army. (1999). *Finding of No Significant Impact for the Life Cycle Environmental Assessment for the HELLFIRE Modular Missile System*. Washington, DC: U.S. Department of Defense.

U.S. Department of the Navy. (1975). *Explosion Effects and Properties Part I – Explosion Effects in Air*. Silver Spring, MD: White Oak Laboratory, Naval Surface Weapons Center.

U.S. Department of the Navy. (1981). *Gun Blast Far Field Peak Overpressure Contours*. (NSWC TR 79-442). Silver Spring, MD: Naval Surface Weapons Center.

U.S. Department of the Navy. (1999). *Environmental Effects of RF Chaff: A Select Panel Report to the Undersecretary of Defense for Environmental Security*. Washington, DC: U.S. Department of the Navy, Naval Research Laboratory.

U.S. Department of the Navy. (2000). *Noise Blast Test Results Aboard the USS Cole*. Dahlgren, VA: Naval Surface Warfare Center Dahlgren Division.

U.S. Department of the Navy. (2001). *Sonic Boom Parametric Study*. Naval Air Station Patuxent River: Applied Ordnance Technology, Inc. and Operational Environmental Planning Office

U.S. Department of the Navy. (2005). *Final Environmental Assessment and Overseas Environmental Assessment for Organic Airborne and Surface Influence Sweep Mission Tests*. Washington, DC: Airborne Mine Defense Program Office, Program Executive Office: Littoral and Mine Warfare.

U.S. Department of the Navy, and Department of Defense. (2007). *Finding of No Significant Harm and Final Environmental Assessment of the Naval Air Routine Training Exercises in East and Gulf Coast Operation Areas and Seaward*. Norfolk, VA: Atlantic Division, Naval Facilities Engineering Command.

U.S. Department of the Navy. (2010). *Laser System Usage in the Marine Environment: Applications and Environmental Considerations*. San Diego, CA: Space and Naval Warfare Systems Command Center Pacific.

U.S. Department of the Navy. (2012a). *Biological Assessment for the Expeditionary Electronic Attack Squadron Realignment and Transition at Naval Air Station Whidbey Island, Oak Harbor, Washington*. Washington, DC: U.S. Department of the Navy.

U.S. Department of the Navy. (2012b). *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis*. San Diego, CA: Naval Facilities Engineering Command, Pacific.

U.S. Department of the Navy. (2014). *U.S. Navy Testing of Hypervelocity Projectiles and an Electromagnetic Railgun*. Wallops Island, VA: U.S. Department of the Navy.

U.S. Department of the Navy. (2016a). *NATOPS General Flight and Operating Instructions; OPNAV Instruction 3710.7V*. Washington, DC: Office of the Chief of Naval Operations.

U.S. Department of the Navy. (2016b). *Building and Maintaining a Comprehensive Database and Prioritization Scheme for Overlapping Habitat Data*. Washington, DC: United States Fleet Forces.

U.S. Department of the Navy. (2017a). *U.S. Navy Marine Species Density Database Phase III for the Hawaii-Southern California Training and Testing Study Area* (Naval Facilities Engineering Command Pacific Technical Report). Pearl Harbor, HI: Naval Facilities Engineering Command Pacific.

U.S. Department of the Navy. (2017b). *U.S. Navy Marine Species Density Database Phase III for the Atlantic Fleet Training and Testing Study Area* (Naval Facilities Engineering Command Atlantic Technical Report). Norfolk, VA: Naval Facilities Engineering Command Atlantic.

U.S. Department of the Navy. (2017c). *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III)*. San Diego, CA: Space and Naval Warfare System Command, Pacific.

U.S. Department of the Navy. (2018). *Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase III Training and Testing* (Technical Report prepared by NUWC Division Newport, Space and Naval Warfare Systems Center Pacific, G2 Software Systems, and the National Marine Mammal Foundation). Newport, RI: Naval Undersea Warfare Center.

U.S. Naval Research Advisory Committee. (2009). *Report on Jet Engine Noise Reduction*. Patuxent River, MD: Department of Defense.

Uchupi, E., and K. O. Emery. (1963). The continental slope between San Francisco, California and Cedros Island, Mexico. *Deep-Sea Research, 10*, 397–447.

Ulrich, R. M. (2004). *Development of a Sensitive and Specific Biosensor Assay to Detect Vibrio vulnificus in Estuarine Waters.* (Master of Science Partial fulfillment of the requirements for the degree of Master of Science Department of Biology College of Arts and Sciences). University of South Florida.

United Nations Educational Scientific and Cultural Organization. (2009). *Global Open Oceans and Deep Seabed—Biogeographic Classification*. Paris, France: UNESCO - IOC.

Urick, R. J. (1983). *Principles of Underwater Sound* (3rd ed.). Los Altos, CA: Peninsula Publishing.

Valiela, I. (1995). *Marine Ecological Processes* (2nd ed.). New York, NY: Springer-Verlag.

Venrick, E. L. (2000). Summer in the Ensenada Front: The distribution of phytoplankton species, July 1985 and September 1988. *Journal of Plankton Research, 22*(5), 813–841.

Vetter, E. W., C. R. Smith, and F. C. De Leo. (2010). Hawaiian hotspots: Enhanced megafaunal abundance and diversity in submarine canyons on the oceanic islands of Hawaii. *Marine Ecology, 31*(1), 183–199.

Wilkinson, C., and G. Hodgson. (1999). Coral Reefs and the 1997–1998 Mass Bleaching and Mortality. *Nature & Resources, 35*(2), 15–25.

Wolanski, E., R. H. Richmond, G. Davis, E. Deleersnijder, and R. R. Leben. (2003). Eddies around Guam, an island in the Mariana Islands group. *Continental Shelf Research, 23*, 991–1003.

Yagla, J., and R. Stiegler. (2003). *Gun blast noise transmission across the air-sea interface*. Paper presented at the 5th European Conference on Noise Control. Naples, Italy.

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3.1 Air Quality

PREFERRED ALTERNATIVE SYNOPSIS

The United States Department of the Navy considered all potential stressors that air quality could be exposed to from the Proposed Action. The following conclusions have been reached for the Preferred Alternative (Alternative 1):

- Criteria air pollutants: The emission of criteria pollutants resulting from activities in the Study Area would not cause a violation or contribute to an ongoing violation of the National Ambient Air Quality Standards.

3.1.1 Introduction

Air pollution is a threat to human health and also damages the environment (U.S. Environmental Protection Agency, 2007a). Air pollution damages trees, crops, other plants, lakes, and animals. In addition to damaging the natural environment, air pollution damages the exteriors of buildings, monuments, and statues. It creates haze or smog that reduces visibility in national parks and cities and interferes with aviation. To improve air quality and reduce air pollution, Congress passed the Clean Air Act in 1963, and its amendments in 1970 and 1990, which set regulatory limits on air pollutants and help to ensure basic health and environmental protection from air pollution.

Air quality is defined by atmospheric concentrations of specific air pollutants—pollutants the United States (U.S.) Environmental Protection Agency (USEPA) determined to be harmful to human health or welfare of the public. The six major air pollutants of concern, called "criteria pollutants," are carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, particulate matter, and lead. Particulate matter is further categorized as particulates less than or equal to 10 microns in diameter and fine particulate matter less than or equal to 2.5 microns in diameter. The Clean Air Act requires that the USEPA establish National Ambient Air Quality Standards for these criteria pollutants. These standards set specific concentration limits for criteria pollutants in the outdoor air. The particular pollutants were chosen because they are common in outdoor air, considered harmful to public health and welfare, and come from numerous and diverse sources. The concentration limits are designed to aid in protecting public health and the environment. Areas with air pollution problems typically have one or more criteria pollutants consistently present at levels that exceed the National Ambient Air Quality Standards. These areas are designated as a nonattainment area for one of those standards, or a maintenance area when a former nonattainment area has recently achieved attainment for an air quality standard that was previously exceeded.

Criteria air pollutants are classified as either primary or secondary pollutants based on how they are formed in the atmosphere. Primary air pollutants are emitted directly into the atmosphere from the source of the pollutant and retain their chemical form. Examples of primary pollutants are the smoke produced by burning wood and volatile organic compounds emitted by industrial solvents. Secondary air pollutants are those formed through atmospheric chemical reactions that usually involve primary air pollutants (or pollutant precursors) and normal constituents of the atmosphere. Ozone, a major component of photochemical smog, is a secondary air pollutant. Ozone precursors, nitrogen oxides, and volatile organic compounds chemically react in the atmosphere in the presence of sunlight to form ground-level ozone.

Some criteria air pollutants are a combination of primary and secondary pollutants. Particulate matter less than or equal to 10 microns in diameter and particulate matter less than or equal to 2.5 microns in diameter are generated as primary pollutants by various mechanical processes (e.g., abrasion, erosion, mixing, or atomization) or combustion processes. They are generated as secondary pollutants through chemical reactions or through the condensation of gaseous pollutants (e.g., nitrogen oxides, sulfur oxides, and volatile organic compounds) into fine aerosols.

In addition to the six criteria pollutants, the USEPA has designated 187 substances as hazardous air pollutants under the federal Clean Air Act. Hazardous air pollutants, also known as toxic air pollutants or air toxics, are those pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects (U.S. Environmental Protection Agency, 2016a). National Ambient Air Quality Standards are not established for these pollutants; however, the USEPA developed rules that limit emissions of hazardous air pollutants from specific industrial sources. These emissions control standards are known as “maximum achievable control technologies” and “generally achievable control technologies.” They are intended to achieve the maximum degree of reduction in emissions of the hazardous air pollutants, taking into consideration the cost of emissions control, non-air-quality health and environmental impacts, and energy requirements. These emissions are typically one or more orders of magnitude smaller than concurrent emissions of criteria air pollutants. Hazardous air pollutants are analyzed qualitatively in relation to the prevalence of the sources emitting these pollutants during training and testing activities. Mobile sources operating as a result of the proposed action would be functioning intermittently over a large area and would produce negligible ambient hazardous air pollutants in a localized area not located near any publicly accessible areas. For these reasons, hazardous air pollutants are not further evaluated in the analysis.

Most air pollutant emissions are expressed as a rate (e.g., pounds per hour, pounds per day, or tons per year). Typical units for emission factors for a source or source activity are pound per thousand gallons of fuel burned, pound per ton of material processed, and grams per vehicle-mile of travel.

Ambient air quality is reported as the atmospheric concentrations of specific air pollutants at a particular time and location. The units of measure are expressed as a mass per unit volume (e.g., micrograms per cubic meter of air) or as a volume fraction (e.g., parts per million [ppm] by volume). The ambient air pollutant concentrations measured at a particular location are determined by the pollutant emissions rate, local meteorology, and atmospheric chemistry. Wind speed and direction, the vertical temperature gradient of the atmosphere, and precipitation patterns affect the dispersal, dilution, and removal of air pollutant emissions from the atmosphere.

3.1.1.1 Air Quality Standards

The current National Ambient Air Quality Standards for criteria pollutants are set forth in Table 3.1-1. Areas that exceed a standard are designated as “nonattainment” for that pollutant, while areas that are in compliance with a standard are in “attainment” for that pollutant. An area may be nonattainment for some pollutants and attainment for others simultaneously. Areas classified as attainment, after being designated as nonattainment, may be reclassified as maintenance areas subject to maintenance plans showing how the area will continue to meet federal air quality standards. Nonattainment areas for some criteria pollutants are further classified, depending upon the severity of their air quality problem, to facilitate their management:

- ozone—marginal, moderate, serious, severe, and extreme

- carbon monoxide—moderate and serious
- particulate matter—moderate and serious

Table 3.1-1: National Ambient Air Quality Standards

Pollutant		*Primary/ Secondary*	*Averaging Time*	*Level*	*Form*
Carbon monoxide		primary	8 hours	9 parts per million	Not to be exceeded more than once per year
			1 hour	35 parts per million	
Lead		primary and secondary	Rolling 3-month period	0.15 micrograms per cubic meter[1]	Not to be exceeded
Nitrogen dioxide		primary	1 hour	100 parts per billion	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		primary and secondary	1 year	53 parts per billion[2]	Annual mean
Ozone		primary and secondary	8 hours	0.070 parts per million[3]	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
Particle Pollution (particulate matter)	particulate matter less than or equal to 2.5 microns in diameter	primary	1 year	12.0 micrograms per cubic meter	Annual mean, averaged over 3 years
		secondary	1 year	15.0 micrograms per cubic meter	Annual mean, averaged over 3 years
		primary and secondary	24 hours	35 micrograms per cubic meter	98th percentile, averaged over 3 years
	particulate matter less than or equal to 10 microns in diameter	primary and secondary	24 hours	150 micrograms per cubic meter	Not to be exceeded more than once per year on average over 3 years
Sulfur dioxide		primary	1 hour	75 parts per billion[4]	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		secondary	3 hours	0.5 parts per million	Not to be exceeded more than once per year

Table 3.1-1: National Ambient Air Quality Standards (continued)

Pollutant	Primary/ Secondary	Averaging Time	Level	Form

Source: (U.S. Environmental Protection Agency, 2016b), last updated January 7, 2016.

[1] In areas designated nonattainment for the lead standards prior to the promulgation of the current (2008) standards, and for which implementation plans to attain or maintain the current (2008) standards have not been submitted and approved, the previous standards (1.5 micrograms per cubic meter as a calendar quarter average) also remain in effect.

[2] The level of the annual nitrogen dioxide standard is 0.053 parts per million. It is shown here in terms of parts per billion for the purposes of clearer comparison to the 1-hour standard level.

[3] Final rule signed October 1, 2015, and effective December 28, 2015. The previous (2008) ozone standards additionally remain in effect in some areas. Revocation of the previous (2008) ozone standards and transitioning to the current (2015) standards will be addressed in the implementation rule for the current standards.

[4] The previous sulfur dioxide standards (0.14 parts per million 24-hour and 0.03 parts per million annual) will additionally remain in effect in certain areas: (1) any area for which it is not yet one year since the effective date of designation under the current (2010) standards, and (2) any area for which implementation plans providing for attainment of the current (2010) standard have not been submitted and approved and which is designated nonattainment under the previous sulfur dioxide standards or is not meeting the requirements of a State Implementation Plan call under the previous sulfur dioxide standards (40 Code of Federal Regulations 50.4(3)). A State Implementation Plan call is a USEPA action requiring a state to resubmit all or part of its State Implementation Plan to demonstrate attainment of the required National Ambient Air Quality Standards.

The USEPA delegates the regulation of air quality to the state once the state has an approved State Implementation Plan. States, through their air quality management agencies, are required under the Clean Air Act to prepare a State Implementation Plan to demonstrate how the nonattainment and maintenance areas will achieve and maintain the National Ambient Air Quality Standards.

If the state fails to develop an adequate plan to achieve and maintain the National Ambient Air Quality Standards, or a State Implementation Plan revision is not approved by USEPA, the EPA will impose a Federal Implementation Plan. States may also choose to adopt the Federal Implementation Plan as an alternative to developing their own State Implementation Plan. States may establish air quality standards more stringent than the National Ambient Air Quality Standards. Regardless of whether EPA has approved a State Implementation Plan, Federal entities have to comply with all federal, state, and local requirements respecting control and abatement of air pollution, as long as the requirements are not discriminatory. That is, they are treated like other regulated entities.

The Clean Air Act applies to coastal waters within 3 nautical miles (NM) of shore. The Hawaii-Southern California Training and Testing (HSTT) Study Area includes areas that are in attainment of the National Ambient Air Quality Standards (including the State of Hawaii and Hawaii State waters), unclassified as to the attainment status (including offshore areas outside of State waters (>3 NM), areas in Federal Waters (>3 NM but <12 NM), as well as all offshore areas beyond Federal waters (>12 NM), and areas that are classified as nonattainment or maintenance areas. With the exception of activities in California's South Coast and San Diego Air Basins, training and testing activities in the Study Area take place either within an attainment area (e.g., State of Hawaii waters) or more than 3 NM from shore in areas unclassified for air quality purposes of the Study Area. Further discussion of the attainment status of the Study Area is provided in Sections 3.1.1.2 (Attainment Areas) and 3.1.1.3 (General Conformity Analysis).

The at-sea areas around San Nicolas Island and Santa Barbara Island are partially within the Study Area. San Nicolas Island is in the Ventura County air district and Santa Barbara Island is in the Santa Barbara

County air district. Both islands are in the South Central Coast Air Basin, which is in attainment for all criteria pollutants (U.S. Environmental Protection Agency, 2017). In addition, emissions from the proposed activities under this EIS within these areas would be minimal. Therefore, impacts to these specific areas are not discussed further.

3.1.1.2 Attainment Areas

The Proposed Action includes activities offshore of Hawaii, which is classified as an attainment area for all criteria pollutants under the National Ambient Air Quality Standards. Within attainment areas, the Navy is required to ensure that air quality does not significantly deteriorate as a result of air emissions associated with training and testing activities conducted under the Proposed Action.

The Prevention of Significant Deterioration Program was adopted in the Clean Air Act under 40 CFR Section 52.21. The Prevention of Significant Deterioration Program applies to major stationary sources of air pollutants located in attainment areas, requiring that a source demonstrate that it does not significantly deteriorate the air quality in attainment areas. Under the Prevention of Significant Deterioration program, a “major source” is defined as a facility that emits equal to or greater than 250 tons of a criteria pollutant or regulated precursor.

In contrast, for nonattainment areas, a major source is defined based on the classification of the area under the Clean Air Act. Further discussion of major source threshold for nonattainment areas is provided in the following sections under General Conformity Evaluation.

3.1.1.3 General Conformity Evaluation

Attainment areas are not subject to the General Conformity Rule. The General Conformity analysis is separate and distinct from the National Environmental Policy Act (NEPA) Analysis below at Section 3.1.1.4 (Approach to Analysis). Conformity is concerned with insuring that non-permitted, non-stationary projects conform to the State Implementation Plan. The Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS) analysis is concerned with whether an activity significantly affects the human environment. The two analyses are related in that an air impact that violates a State Implementation Plan is probably “significant” in NEPA terms. Section 176(c)(1) of the Clean Air Act, commonly known as the General Conformity Rule, requires federal agencies to ensure that their actions conform to applicable implementation plans for achieving and maintaining the National Ambient Air Quality Standards for criteria pollutants for nonattainment and maintenance areas. Federal actions are required to conform with the approved State Implementation Plan for those areas of the United States designated as nonattainment or maintenance areas for any criteria air pollutant under the Clean Air Act (40 Code of Federal Regulations [CFR] Parts 51 and 93). The purpose of the General Conformity Rule is to ensure that applicable federal actions within the area regulated by the Clean Air Act would not cause or contribute to a violation of an air quality standard and that the Proposed Action would not adversely affect the attainment and maintenance of National Ambient Air Quality Standards. A conformity evaluation must be completed for every applicable Navy action that generates emissions to determine and document whether a proposed action complies with the General Conformity Rule.

Conformity only applies to nonattainment and maintenance areas for nonattainment and maintenance pollutants and their regulated precursors. Certain Navy training and testing activities take place within nonattainment and maintenance areas. These nonattainment and maintenance areas are identified by their air quality control region (an area designated by the federal government where communities share a common air pollution problem). Two such designated areas in California (South Coast and San Diego;

Figure 3.1-1) were identified as relevant to the Proposed Action and are further discussed in Section 3.1.2.2 (Existing Air Quality).

If a federal action is not an emergency response action presumed to conform under the Rule, does not meet the approved facility emissions budget, is not a listed exempt activity, and is not covered by the Transportation Conformity Rule, then a conformity demonstration evaluating total direct and indirect emissions must be made. The total direct and indirect emissions evaluation considers emission increases that are reasonably foreseeable at the time the Conformity analysis is conducted. Unlike NEPA, there is no need to discuss alternatives or “no action” alternatives. The only relevant emissions are the net increase when all increases and decreases are considered.

The first step in the Conformity analysis is a Conformity Applicability Analysis and involves calculating the non-exempt direct and indirect emissions associated with the action. If there is no current activity (the proposed action is completely new), then the sum of the non-exempt direct and indirect emissions equals the net change in emissions (the current level would be zero). If the action is a change from a current level of emissions, then the current level is defined as the baseline that future emissions are evaluated against. The net change, then, is the difference between the emissions associated with the action and the baseline emissions. The net change may be positive, negative, or zero. The emissions thresholds that trigger the conformity requirements are called *de minimis* levels. The net change calculated for the direct and indirect emissions are compared to the *de minimis* levels. If the net change in emissions do not exceed *de minimis* thresholds, then a General Conformity Determination is not required. The emissions are presumed to conform to the State Implementation Plan. If the net change in emissions equal or exceed the *de minimis* conformity applicability threshold values, a formal Conformity Determination must be prepared to demonstrate conformity with the approved State Implementation Plan.

The Navy Guidance for Compliance with the Clean Air Act General Conformity Rule, section 4.1, states that a Record of Non-Applicability must be prepared if the proposed action is subject to the Conformity Rule, but is exempt because it fits within one of the exemption categories listed under 40 CFR 93B, because the action’s projected emissions are below the *de minimis* conformity applicability threshold values, or is presumed to conform (U.S. Department of the Navy, 2013).The *de minimis* levels for nonattainment and maintenance pollutants under the General Conformity Rule are shown in Table 3.1-2.

If NEPA documentation is prepared for an action, the determination that the proposed action is not subject to the General Conformity Rule can be described in that documentation. Otherwise, no documentation is required.

Coastal waters within 3 NM of the coast are under the same air quality jurisdiction as the contiguous land area.

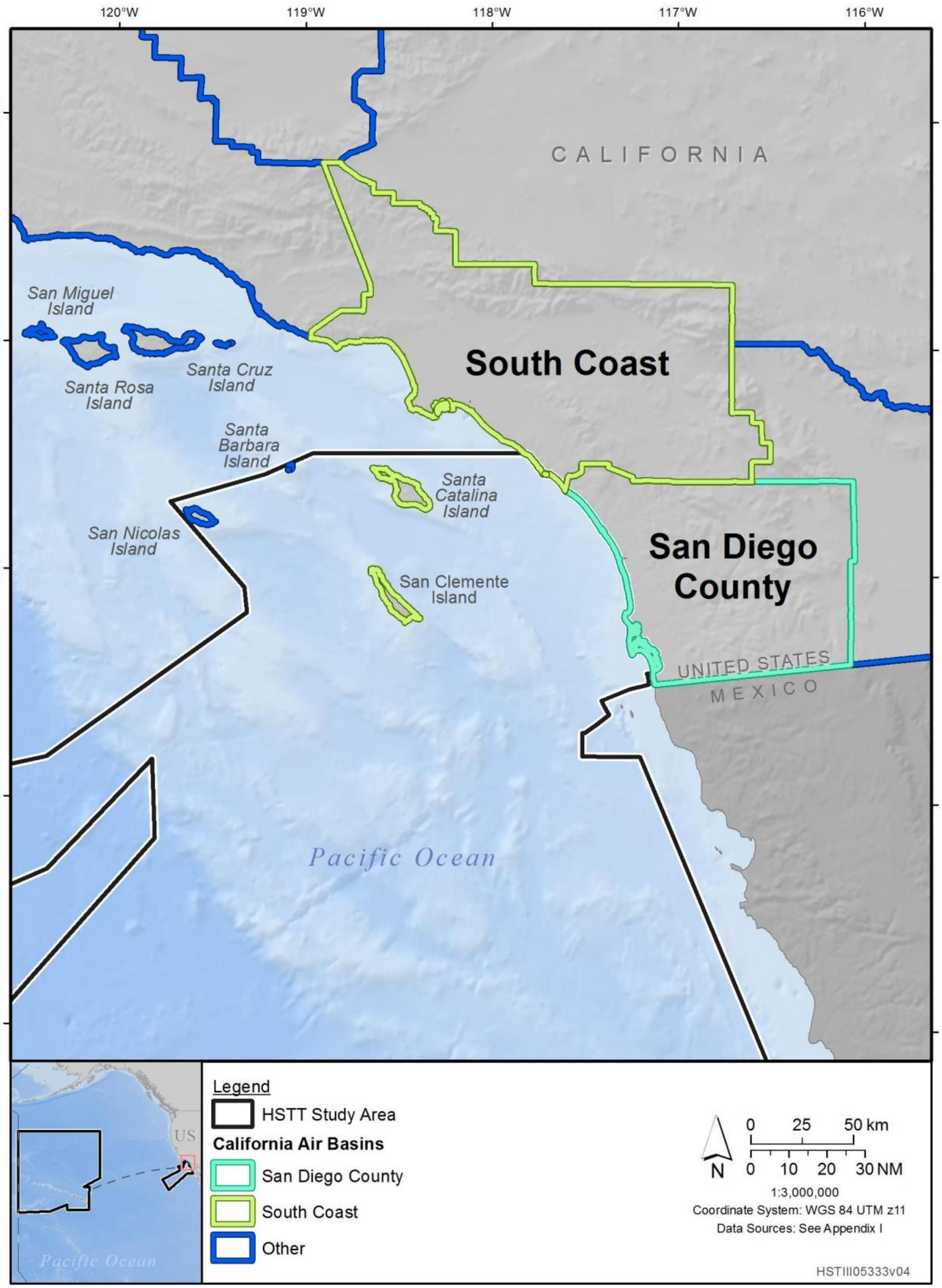

Figure 3.1-1: Air Basins Adjacent to the Southern California Portion of the HSTT Study Area

Note: HSTT = Hawaii-Southern California Training and Testing

Table 3.1-2: *De Minimis* Thresholds for Conformity Determinations

Pollutant	Nonattainment or Maintenance Area Type	de minimis Threshold (TPY)
Ozone (VOC or NO_X)	Serious nonattainment	50
	Severe nonattainment	25
	Extreme nonattainment	10
	Other areas outside an ozone transport region	100
Ozone (NO_X)	Marginal and moderate nonattainment inside an ozone transport region	100
	Maintenance	100
Ozone (VOC)	Marginal and moderate nonattainment inside an ozone transport region	50
	Maintenance within an ozone transport region	50
	Maintenance outside an ozone transport region	100
CO, SO_2 and NO_2	All nonattainment and maintenance	100
PM_{10}	Serious nonattainment	70
	Moderate nonattainment and maintenance	100
$PM_{2.5}$	Serious nonattainment	70
	Moderate nonattainment and maintenance	100
Lead (Pb)	All nonattainment and maintenance	25

Source: (U.S. Environmental Protection Agency, 2010)
Notes: CO = carbon monoxide, NO_X = nitrogen oxides, NO_2 = nitrogen dioxide, PM_{10} = particulate matter ≤ 10 microns in diameter, $PM_{2.5}$ = particulate matter ≤ 2.5 microns in diameter, SO_2 = sulfur dioxide, SO_X = sulfur oxides, TPY = tons per year, VOC = volatile organic compound

3.1.1.3.1.1 Conformity Analysis South Coast Air Basin (California)

The Proposed Action includes activities in the South Coast Air Basin, which is classified as an extreme nonattainment area for the 2008 eight-hour ozone standard; as a maintenance area for carbon monoxide, nitrogen dioxide, particulate matter equal to or less than 10 microns in diameter; and as a serious nonattainment area for particulate matter equal to or less than 2.5 microns in diameter. The Proposed Action is required to demonstrate conformity with the approved State Implementation Plan if the net emissions equal or exceed the *de minimis* emission levels in nonattainment and maintenance areas. If the net emissions are below the *de minimis* emission levels in nonattainment and maintenance areas, a Record of Non-Applicability must be prepared. The *de minimis* levels for nonattainment and maintenance pollutants in the South Coast Air Basin under the General Conformity Rule are shown in Table 3.1-2.

3.1.1.3.1.2 Conformity Analysis San Diego Air Basin (California)

The Proposed Action includes activities that occur in the San Diego Air Basin, which is currently designated a moderate nonattainment area for the 2008 federal eight-hour ozone standard and a maintenance area for carbon monoxide. The Proposed Action is required to demonstrate conformity with the approved State Implementation Plan if the net emissions equal or exceed the *de minimis* emission levels in nonattainment and maintenance areas. If the net emissions are below the *de minimis* emission levels in nonattainment and maintenance areas, a Record of Non-Applicability must be prepared. The *de minimis* levels for nonattainment and maintenance pollutants in the San Diego Air Basin under the General Conformity Rule are shown in Table 3.1-2.

3.1.1.4 Approach to Analysis

3.1.1.4.1 Boundaries of Analysis

The air quality impact evaluation requires three separate analyses: the Clean Air Act General Conformity Analysis, an analysis under NEPA, and an analysis under Executive Order 12114. Impacts of air pollutants emitted by Navy training and testing in the Pacific Ocean, bays and inland locations in U.S. territorial seas (i.e., up to 12 NM from the coast) are assessed under NEPA. Impacts of air pollutants emitted by Navy training and testing activities outside of U.S. territorial seas are evaluated as required under Executive Order 12114 (Environmental Effects Abroad of Major Federal Action). Each coastal state may claim the territorial sea that extends seaward up to 12 NM from its baselines. The coastal State exercises sovereignty over its territorial sea, the air space above it, and the seabed and subsoil beneath it (National Oceanic and Atmospheric Administration, 2017). The State jurisdictions may extend the full distance of territorial seas or may retain historical limits.

The air quality evaluation under the Clean Air Act General Conformity Rule requires an analysis of impacts of air pollutants within state air quality jurisdictions, which are defined as the portions of the Study Area that lie within 3 NM of the coastline of a given jurisdiction. As discussed in Section 3.1.1.3 (General Conformity Evaluation), impacts of air pollutants emitted by Navy training and testing in the Pacific Ocean, bays and inland locations in State waters (i.e., up to 3 NM from the coast) are assessed under the General Conformity Rule of the Clean Air Act and under NEPA. For the purpose of this EIS/OEIS, a comparison of the emissions within 3 NM of the coastline of nonattainment areas in the Study Area has been provided within the analysis of Environmental Consequences.

Air pollutants emitted more than 3,000 feet (ft.) above ground level are considered to be above the atmospheric inversion layer and, therefore, do not affect ground-level air quality (U.S. Environmental Protection Agency, 1992). These emissions thus do not affect the concentrations of criteria air pollutants in the lower atmosphere, measured at ground-level monitoring stations, upon which federal, state, and local regulatory decisions are based. For the analysis of the effects on global climate change, however, all emissions of greenhouse gases from aircraft and vessels participating in training and testing activities, as well as targets and munitions expended, are applicable regardless of altitude (Chapter 4, Cumulative Impacts).

Analysis of health-based air quality impacts under NEPA and Executive Order 12114 includes estimates of criteria air pollutants for all training and testing activities where aircraft, missiles, or targets operate at or below the aforementioned inversion layer or that involve vessels in U.S. territorial seas. The analysis of health- based air quality impacts under Executive Order 12114 includes emissions estimates of only those training and testing activities in which aircraft, missiles, or targets operate at or below 3,000 ft. above ground level, or that involve vessels outside of U.S. territorial seas.

In determining the total direct and indirect emissions caused by the action, agencies must project the future emissions in the area with the action versus the future emissions without the action, what NEPA entitles “the no build option.” The total direct and indirect emissions considers all emission increases and decreases and must be reasonably foreseeable and are possibly controllable through agency’s continuing program responsibility to affect emissions.

3.1.1.4.2 Emission Sources

Criteria air pollutants are generated by the combustion of fuel by surface vessels and by fixed-wing and rotary-wing aircraft. They also are generated by the combustion of explosives and propellants in various types of munitions. Propellants used to fire small-, medium-, and large-caliber projectiles generate criteria pollutants when detonated. Nonexplosive practice munitions may contain spotting charges and propellants that generate criteria air pollutants when they function. Powered targets require fuel, generating criteria air pollutants during their operation, and towed targets generate criteria air pollutants secondarily because another aircraft or vessel is required to provide power. Stationary targets may generate criteria air pollutants if all or portions of the item burn in a high-order detonation. Chaff cartridges used by ships and aircraft are launched by an explosive charge that generates small quantities of criteria air pollutants. Countermeasure flares, decelerators/parachute flares, and smoke floats are designed to burn for a prescribed period, emitting criteria pollutants in the process.

The primary emissions from many munition types are carbon dioxide, carbon monoxide, and particulate matter; hazardous air pollutants are emitted at low levels (U.S. Environmental Protection Agency, 2007b, 2008a, 2009a). Hazardous air pollutants are analyzed qualitatively in relation to the prevalence of the sources emitting hazardous air pollutants during training and testing activities.

Electronic warfare countermeasures generate emissions of chaff, a form of particulate not regulated under the federal Clean Air Act as a criteria air pollutant. Virtually all radio frequency chaff is 10–100 times larger than regulated particulate matter (i.e., particulate matter less than or equal to 10 microns in diameter and particulate matter less than or equal to 2.5 microns in diameter (Spargo et al., 1999)). The types of training and testing that produce these other emissions may take place throughout the Study Area but occur primarily within special use airspace. Chaff emissions during training and testing primarily occur 3 NM or more from shore. Chaff released over the ocean would disperse in the atmosphere and then settle onto the ocean surface.

A study at Naval Air Station Fallon found that the release of 50,000 cartridges of chaff per year over 10,000 square miles (m^2) would result in an annual average concentration of 0.018 $\mu g/m^3$ for regulated particulate matter. This is far below the National Ambient Air Quality Standards. Similar predictions were made for St. Mary's County, Maryland (on the Chesapeake Bay), where chaff releases contribute no more than 0.008 percent of total particulate matter emissions (Arfsten et al., 2001). Therefore, chaff is not further evaluated as an air quality stressor in this EIS/OEIS.

3.1.1.4.3 Analysis Framework

Emission sources and the approach used to estimate emissions under Alternative 1 and Alternative 2 in the air quality analysis are based, wherever possible, on information from Navy subject matter experts and established training and testing requirements. These data were used to estimate the numbers and types of aircraft, surface ships and vessels, submarines, and munitions (i.e., potential sources of air emissions) that would be involved in training and testing activities under each alternative. Emissions were assessed to identify any possibility for the magnitude of Proposed Action emissions to result in a violation of one or more Ambient Air Quality Standards. It should also be noted that the focus of the analysis is on the net increase in emissions that would result from the two action alternatives over the baseline evaluated in the 2013 Final EIS/OEIS.

This analysis makes use of "screening thresholds," which are defined as thresholds of potential significance that are based on legal standards that are either legislated or contained in regulations promulgated by expert agencies with the input of the public and scientific community, as well as the input of the legal and judicial community. If the emissions projected in any of the regions exceed a screening threshold, then they deserve a more thorough, closer examination. The greater the exceedance, the more rigorous the examination needs to be. In this case, relevant emissions are not expected to exceed any screening threshold or significantly impact the human environment.

In attainment areas and over the study area that is outside jurisdictional boundaries, a screening level of 250 tons per year of any criteria pollutant or regulated precursor has been used as a threshold of potential significance. Although outlying areas are not classified, they are presumed to be analogous to attainment areas. In nonattainment and maintenance areas we are using conformity *de minimis* levels, which are the same as major source thresholds. These thresholds are rational to use for potential significance thresholds, because they are borrowed from laws and regulations that view them as thresholds of increased regulatory concern. They are also conservative, because they are taken from authorities that regulate stationary sources and land-based projects such as new facilities. However, these emissions are actually emitted over a vast area of ocean and dispersed very widely over that area. These thresholds also take cumulative effects into account, because they are smaller in areas of degraded air. In this way, they take into account impacts of past and present activity, as well as the outlook for future attainment in an area.

3.1.1.5 Emissions Estimates

As discussed in Section 3.1.1.4 (Approach to Analysis), the focus of the analysis is on the net increase in emissions that would result from the two action alternatives over the baseline. The baseline is the Preferred Alternative that was evaluated in the 2013 Final EIS/OEIS and selected in the Record of Decision. The Navy has provided improved emission factor data for ships and aircraft that have been updated since the 2013 Final EIS/OEIS. The baseline calculations have been updated to reflect the current emission factor data.

3.1.1.5.1 Aircraft Activities

To estimate aircraft emissions, the operating modes, number of hours of operation, and type of engine for each type of aircraft were evaluated.

Emissions associated with airfield or air station operations ashore are analyzed within the home-basing environmental planning process (U.S. Department of the Navy, 2007, 2009, 2010, 2013, 2014). All fixed-wing aircraft are assumed to travel to and from training and testing ranges at or above 3,000 ft. above mean sea level and, therefore, their transits to and from the ranges do not affect surface air quality. Air combat maneuvers and air-to-air missile exercises are primarily conducted at altitudes well in excess of 3,000 feet above mean sea level and, therefore, are not included in the estimated emissions of criteria air pollutants. Activities or portions of those training or testing activities occurring below 3,000 ft. are included in emissions estimates. Examples of activities typically occurring below 3,000 ft. include those involving rotary-wing aircraft platforms such as mine warfare, surface warfare, and anti-submarine warfare training and testing activities. The number of all training and testing activities and the estimated time spent above or below 3,000 ft. for calculation purposes is included in the air quality emissions estimates presented in Appendix C (Air Quality Emissions Calculations and Record of Non-Applicability).

The types of aircraft identified include the typical aircraft platforms that conduct a particular training or testing exercise (or the closest surrogate when information is not available), including range support aircraft (e.g., non-Navy commercial air services). Estimates of future aircraft sorties are based on evolutionary changes in the Navy's force structure and mission assignments. Where there are no major changes in types of aircraft, future activity levels are estimated from the distribution of baseline activities. The types of aircraft used in each training or testing activity and numbers of sorties flown by such aircraft are presented in Appendix C (Air Quality Emissions Calculations and Record of Non-Applicability).

Several testing activities are similar to training activities, and therefore similar assumptions were made for such activities in terms of aircraft type, altitude, and flight duration. Table 2.6-2 lists Naval Air Systems Command testing activities similar to certain training activities. Where aircraft testing activities were dissimilar to training activities, assumptions for time on range were derived from Navy subject matter experts.

Air pollutant emissions from aircraft were primarily estimated based on the Navy's Aircraft Environmental Support Office Memorandum Reports for individual aircraft categories. When Aircraft Environmental Support Office emission factor data were not available, emission factors were obtained from other published sources.

The emissions calculations performed for each alternative conservatively assume that each aircraft training and testing activity listed in Tables 2.6-1 to 2.6-5 is separately conducted. In practice, a testing activity may be conducted during a training flight. It is also probable that two or more training activities may be conducted during one flight (e.g., chaff or flare exercises may occur during electronic warfare activities; or air-to-surface gunnery and air-to-surface bombing activities may occur during a single flight operation). Conservative assumptions may produce elevated aircraft emissions calculations but accounts for the possibility, however remote, that each aircraft training and testing activity is separately conducted.

3.1.1.5.2 Military Vessel Activities

Military vessel traffic in the Study Area includes military ships and smaller boats providing services for military training and testing activities. The methods for estimating military ship and boat emissions involve evaluating the type of activity and generating the average running hours for ships in each operational area, both within state waters and beyond state waters. The types of military ships and boats as well as the numbers of activities for Alternatives 1 and 2 are derived from range records and Navy subject matter experts regarding ship participant data. Estimates of future military vessel activities are based on anticipated evolutionary changes in the Navy's force structure and mission assignments. Where there are no major changes in types of military vessel, estimates of future activities are based on the historical distribution of military vessel activities. This was done to create annual averages for the years 2010 through 2015. The average annual hours were used for Alternative 1. For Alternative 2, the year with the highest number of operational hours (2010) was selected as the year to represent maximum operations. For both alternatives, the hourly data was used in conjunction with emission factors data generated from the Naval Sea Systems Command Navy and Military Sealift Command Marine Engine Fuel Consumption and Emission Calculator to calculate the emissions from the propulsion and onboard generation systems. Data from the calculator included emission factors for each type of propulsion engine and type of onboard electrical power generation system by ship type, as well as the fuel used by engine systems. The resulting calculations provided information on the time spent at each power level in each part of the Study Area, emission factors for that power level (in pounds of pollutant per hour), and total emissions for each marine vessel for each operational type and mode.

The pollutants for which calculations are made include exhaust total hydrocarbons, carbon monoxide, nitrogen oxides, particulate matter, sulfur dioxide, and carbon dioxide. For marine military engines, 100 percent of all of the particulate matter less than or equal to 10 microns in diameter from gasoline and diesel-fueled engines is assumed to be particulate matter less than or equal to 2.5 microns in diameter (U.S. Environmental Protection Agency, 2010b). For gaseous-fueled engines (liquefied petroleum gas/compressed natural gas), 100 percent of the particulate matter emissions are assumed to be particulate matter less than or equal to 2.5 microns in diameter (U.S. Environmental Protection Agency, 2010b).

The emissions calculations performed for each alternative conservatively assume that each vessel training and testing activity listed in Chapter 2 (Description of Proposed Action and Alternatives), Tables 2.6-1 to 2.6-5, is separately conducted and separately produces vessel emissions. In practice, one or more testing activities may take advantage of an opportunity to travel at sea and test aboard a vessel conducting a related or unrelated training activity. It is also probable that two or more training activities may be conducted during one training vessel movement (e.g., a ship may conduct large-, medium-, and small-caliber surface-to-surface gunnery exercises during one vessel movement). Furthermore, multiple unit-level training activities may be conducted during a larger composite training unit exercise. Conservative assumptions may produce elevated vessel emissions calculations but account for the possibility, however remote, that each training and testing activity is separately conducted.

3.1.1.5.3 Submarine Activities

No U.S. submarines burn fossil fuel under normal operating conditions (they are nuclear-powered); therefore, no air pollutants are emitted during submarine training or testing activities.

3.1.1.5.4 Naval Gunfire, Missiles, Bombs, Other Munitions and Military Expended Material

Naval gunfire, missiles, bombs, and other types of munitions used in training and testing activities emit air pollutants. To estimate the amounts of air pollutants emitted by munitions during its use, the numbers and types of munitions used during training or testing activities are first totaled. Then generally accepted emissions factors (U.S. Department of the Navy, 2017; U.S. Environmental Protection Agency, 2007a, 2008b, 2009b) for criteria air pollutants are applied to the total amounts. Finally, the total amounts of air pollutants emitted by each munition type are summed to produce total amounts of each criteria air pollutant under each alternative.

3.1.1.6 Climate Change

Greenhouse gases are compounds that contribute to the greenhouse effect—a natural phenomenon in which gases trap heat in the lowest layer of the earth's atmosphere (surface-troposphere system), causing heating (radiative forcing) at the surface of the earth. The primary long-lived greenhouse gases directly emitted by human activities are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride. Carbon dioxide, methane, and nitrous oxide occur naturally in the atmosphere. These gases influence global climate by trapping heat in the atmosphere that would otherwise escape to space. The heating effect of these gases is considered the probable cause of the global warming observed over the last 50 years (U.S. Environmental Protection Agency, 2009c). Global warming and climate change affects many aspects of the environment. Not all effects of greenhouse gases are related to climate. For example, elevated concentrations of carbon dioxide can lead to ocean acidification and stimulate terrestrial plant growth, and methane emissions can contribute to higher ozone levels.

The administrator of the USEPA determined that greenhouse gases in combination endanger both the public health and the public welfare of current and future generations. The USEPA specifically identified carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride as greenhouse gases (U.S. Environmental Protection Agency, 2009b) (74 Federal Register 66496).

To estimate global warming potential, the United States quantifies greenhouse gas emissions using the 100-year timeframe values established in the Intergovernmental Panel on Climate Change Fourth Assessment Report (Intergovernmental Panel on Climate Change, 2014), in accordance with United Nations Framework Convention on Climate Change (United Nations Framework Convention on Climate Change, 2013) reporting procedures. All global warming potentials are expressed relative to a reference gas, carbon dioxide, which is assigned a global warming potential equal to 1. Six other primary greenhouse gases have global warming potentials of 25 for methane, 298 for nitrous oxide, 124 to 14,800 for hydrofluorocarbons, 7,390 to greater than 17,340 for perfluorocarbons, 17,200 for nitrogen trifluoride, and up to 22,800 for sulfur hexafluoride. To estimate the carbon dioxide equivalency of a non-carbon dioxide greenhouse gas, the appropriate global warming potential of that gas is multiplied by the amount of the gas emitted. All seven greenhouse gases are multiplied by their global warming potential and the results are added to calculate the total equivalent emissions of carbon dioxide. The dominant greenhouse gas emitted is carbon dioxide, mostly from fossil fuel combustion (85.4 percent) (U.S. Environmental Protection Agency, 2015). Weighted by global warming potential, methane is the second-largest component of emissions, followed by nitrous oxide. Global warming potential-weighted emissions are presented in terms of equivalent emissions of carbon dioxide, using units of metric ton. The Proposed Action is anticipated to release greenhouse gases to the atmosphere. These emissions are quantified primarily using methods elaborated upon in the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2014 for the proposed Navy training and testing in the Study Area, and estimates are presented in Chapter 4 (Cumulative Impacts). (U.S. Environmental Protection Agency, 2016b).

3.1.1.7 Other Compliance Considerations, Requirements, and Practices

Executive Order 13834, *Executive Order Regarding Efficient Federal Operations,* issued on May 17, 2018, establishes policy for federal agencies to prioritize actions that reduce waste, cut costs, enhance the resilience of Federal infrastructure and operations, and enable more effective accomplishment of their missions.

In January 2018, the Department of Defense (DoD) published the results of a global screening level assessment of installation vulnerabilities to climate-related security risks with the goal of identifying serious vulnerabilities and developing necessary adaptation strategies. The survey evaluated risk from flooding, extreme temperatures, wind, drought and wildfire.

In June 2014, DoD released the 2014 Climate Change Adaptation Roadmap to document DoD's efforts to plan for the changes that are occurring or expected to occur as a result of climate change. The Roadmap provides an overview and specific details on how DoD's adaptation will occur and describes ongoing efforts (U.S. Department of Defense, 2014).

The Navy is committed to improving energy security and environmental stewardship by reducing reliance on fossil fuels. The Navy is actively developing and participating in energy, environmental, and climate change initiatives that will increase use of alternative energy and reduce emissions of greenhouse gases. The Navy has adopted energy, environmental, and climate change goals. These goals include increasing alternative energy use Navy-wide to 50 percent by 2020; reducing non-tactical petroleum use; ensuring environmentally sound acquisition practices; and ensuring environmentally compliant operations for ships, submarines, aircraft, and facilities operated by the Navy.

Equipment used by military units in the Study Area, including ships and other marine vessels, aircraft, and other equipment, are properly maintained and fueled in accordance with applicable Navy requirements. Operating equipment meets federal and state emission standards, where applicable.

3.1.2 AFFECTED ENVIRONMENT

3.1.2.1 General Background

3.1.2.1.1 Region of Influence

The region of influence for air quality is a function of the type of pollutant, emission rates of the pollutant source, proximity to other emission sources, and local and regional meteorology. For inert pollutants (all pollutants other than particulate matter less than or equal to 10 microns in diameter, particulate matter less than or equal to 2.5 microns in diameter, ozone, and their precursors), the region of influence is generally limited to a few miles downwind from the source. For a photochemical pollutant such as ozone, however, the region of influence may extend much farther downwind. Ozone is a secondary pollutant formed in the atmosphere by photochemical reactions of previously emitted pollutants, or precursors (volatile organic compounds and nitrogen oxides). The maximum impacts of precursors on ozone levels tend to occur several hours after the time of emission during periods of high solar load, and may occur many miles from the source. Ozone and ozone precursors transported from other regions can also combine with local emissions to produce high local ozone concentrations. Therefore, the region of influence for air quality includes the Study Area as well as adjoining land areas several miles inland, which may from time to time be downwind from emission sources associated with the Proposed Action.

3.1.2.1.2 Sensitive Receptors

Identification of sensitive receptors is part of describing the existing air quality environment. Sensitive receptors are individuals in residential areas, schools, parks, hospitals, or other sites for which there is a reasonable expectation of continuous human exposure during the timeframe coinciding with peak pollution concentrations. On the oceanic portions of the Study Area, crews of commercial vessels and recreational users of the northern Atlantic Ocean and Gulf of Mexico could encounter the air pollutants generated by the Proposed Action. Few such individuals are expected to be present and the duration of substantial exposure to these pollutants is limited because the areas are cleared of nonparticipants before event commencement. These potential receptors are not considered sensitive.

3.1.2.1.3 Climate of the Study Area

The climate conditions in the Study Area provide background on factors influencing air quality. Climate zones within the Study Area vary with latitude or region. The climate of the Pacific Ocean and adjacent land areas is influenced by the temperatures of the surface waters and water currents as well as by wind blowing across the water. Offshore climates are moderate, and seldom have extreme seasonal variations because the ocean is slow to change temperature. Ocean currents influence climate by moving warm and cold water between regions. Adjacent land areas are affected by the wind that is cooled or warmed when blowing over these currents. In addition to its influence on temperature, the wind moves evaporated moisture from the ocean to adjacent land areas and is a major source of rainfall.

Atmospheric stability and mixing height provide measures of the amount of vertical mixing of pollutants. Over water, the atmosphere tends to be neutral to slightly unstable. Over land, atmospheric stability is more variable, being unstable during the day, especially in summer due to rapid surface heating, and stable at night, especially under clear conditions in winter. The mixing height over water typically ranges from 1,640 to 3,281 ft. with a slight diurnal (daytime) variation (U.S. Environmental Protection Agency, 1972). The air quality analysis presented in this EIS/OEIS assumes that 3,000 ft. (40 CFR 93.153(c)(2)(iii) above ground level is the typical maximum afternoon mixing height, and thus air pollutants emitted above this altitude do not affect ground-level air pollutant concentrations.

With the advent of human-induced climate change, spatial and temporal variations in weather patterns have emerged or have become more pronounced. Very heavy precipitation events have increased across the eastern half of the United States, with the most pronounced increase involving the mid-Atlantic and New England states (Melillo et al. 2014). Other changes apparent along the eastern seaboard include the rising incidence of heat waves and their extended duration and coastal flooding due to sea level rise and storm surge. In the South and along the Gulf Coast, the incidence of extreme storms, such as hurricanes, continues to rise. These changes to weather patterns have long-term consequences for regional climates and the flora and fauna of the regions.

3.1.2.1.3.1 Hawaii

The climate of the Pacific Ocean offshore of the Hawaiian Islands is subtropical. Offshore winds are predominantly from the north, northeast, and east at 10 to 20 miles per hour. Air temperatures are moderate and vary slightly by season, ranging from about 70 to 80 degrees Fahrenheit. Estimated annual rainfall in ocean areas offshore of Hawaii is estimated at about 25 inches (in.), with most rainfall during the winter season (Western Regional Climate Center, 2016a).

The climate of Hawaii influences air quality in several ways. The prevailing trade winds provide strong, regular regional ventilation that quickly disperses air pollutants and breaks up inversion layers. Frequent rainfall on windward sides of the islands washes dust and other air pollutants out of the atmosphere. During mild Kona (i.e., absence of daily trade winds) weather, local air pollutant concentrations may temporarily increase and volcanic organic gases emissions from the Island of Hawaii may temporarily affect the other islands in the Main Hawaiian Islands.

3.1.2.1.3.2 Southern California

The climate of coastal Southern California and adjacent offshore Pacific Ocean waters consists of warm, dry summers and cool, wet winters. One of the main influences on the climate is a semi-permanent high-pressure system (the Pacific High) in the eastern Pacific Ocean. This high-pressure cell maintains clear skies in Southern California for much of the year. When the Pacific High moves south during the winter, this pattern changes and low-pressure centers migrate into the region, causing widespread precipitation.

The Pacific High influences the large-scale wind patterns of California. The predominant regional wind directions are westerly and west-southwesterly during all four seasons. Surface winds typically are from the west (onshore) during the day and from the east (offshore) at night; this diurnal wind pattern is dominant in winter but is weak or absent in summer, when onshore winds may occur both day and night. Along the coast, average wind speeds are low at night, increase during morning hours to a midday peak, then decrease through the afternoon.

Precipitation in coastal Southern California falls almost exclusively as rain. Most of this precipitation falls from late fall through early spring. No measurements are available for the open ocean; rainfall in coastal San Diego County averages about 9.8 in. per year, and rainfall in coastal Los Angeles averages about 14.8 in. (Western Regional Climate Center, 2016b).

3.1.2.2 Existing Air Quality

Air quality in offshore ocean areas is generally higher than the air quality of adjacent onshore areas because there are few or no large sources of criteria air pollutants offshore. Much of the air pollutants found in offshore areas are transported there from adjacent land areas by low-level offshore winds, so concentrations of criteria air pollutants generally decrease with increasing distance from land. No criteria air pollutant monitoring stations are located in offshore areas, so air quality in the Study Area must be inferred from the air quality in adjacent land areas where air pollutant concentrations are monitored.

3.1.2.2.1 Hawaii

Air quality in Hawaii is generally good, because of the small number of major stationary sources and strong ventilation provided by frequent trade winds. Monitored air pollutant concentrations are generally well below State of Hawaii or federal air quality standards. With the exception of short-term sulfur dioxide measurements recorded near volcanic activity, between 2012 and 2014, none of the air quality monitoring stations in Hawaii recorded criteria air pollutant concentrations that exceeded the ambient air quality standards (Hawaii Department of Health, 2016). The entire State of Hawaii is in attainment of the National Ambient Air Quality Standards and State Ambient Air Quality Standards for all criteria air pollutants. Therefore, a Conformity Determination is not required for those elements of the Proposed Action that occur in Hawaii State waters.

3.1.2.2.2 Southern California Portion of the HSTT Study Area

Figure 3.1-1 presents a map of the air basins in the vicinity of the Southern California Portion of the HSTT Study Area.

3.1.2.2.2.1 South Coast Air Basin

South Coast Air Basin is classified as an extreme non-attainment area for ozone (eight-hour average concentration) under the National Ambient Air Quality Standards, a carbon monoxide maintenance area, a maintenance area for nitrogen dioxide, a maintenance area for particulate matter with a diameter less than or equal to 10 microns, and a serious non-attainment area for particulate matter with a diameter less than or equal to 2.5 microns.

3.1.2.2.2.2 San Diego Air Basin

Air quality in the San Diego Air Basin is classified as a non-attainment area for ozone (eight-hour average concentration) under the National Ambient Air Quality Standards, and as a maintenance area for carbon monoxide. The USEPA designated San Diego County as a “moderate” ozone nonattainment area under the 2008 eight-hour ozone standard.

3.1.2.2.3 Transit Corridor

Air quality in the Transit Corridor, which is more remote from major stationary sources of air pollutants than either the Southern California or the Hawaii Range Complex, is unknown but is expected to be of higher quality than either of these areas. Activities within the Transit Corridor involve the movement of ships and aircraft to training and testing areas. Because the movement of these assets would not be solely attributable to training and testing activities associated with the Proposed Action, emissions associated with these transits have not been quantified for this analysis.

3.1.3 Environmental Consequences

This section evaluates how and to what degree the activities described in Chapter 2 (Description of Proposed Action and Alternatives) potentially impact air quality within the Study Area. Tables 3.1-3 to 3.1-10 present the total emissions for the baseline and proposed training and testing activity locations under each alternative. The air quality stressors vary in intensity, frequency, duration, and location within the Study Area. The stressor applicable to air quality in the Study Area is analyzed below:

- Criteria Air Pollutants

In this analysis, criteria air pollutant emissions estimates were calculated for vessels, aircraft, and munitions. For each alternative, emissions estimates were developed by sub-region of the Study Area and other training and testing locations and totaled for the Study Area. The net emissions increases in the various sub regions under the two action alternatives were then compared to the screening thresholds as described above in the Analysis Framework as a step in the determination of significant impact.

The current (baseline) activities are not reflected in any alternative in this EIS/OEIS, but were described in the Preferred Alternative of the Navy's 2013 HSTT Final EIS/OEIS.

Activities conducted as part of the Proposed Action would involve mobile sources using fossil fuel combustion as a source of power. Greenhouse gas emissions were calculated for vessels, aircraft, and munitions using emissions factors provided by the U.S. Navy for aircraft and vessels, and published by the USEPA for munitions.

Details of the emission estimates are provided in Appendix C (Air Quality Emissions Calculations and Record of Non-Applicability).

3.1.3.1 Criteria Air Pollutants

The potential impacts of criteria air pollutants are evaluated by first estimating the emissions from training and testing activities in the Study Area for each alternative. These estimates are then used to determine the potential impact of the emissions on the attainment status of the adjacent designated air quality area. For a nonattainment or maintenance area, this involves evaluating the net change in emissions that would result from implementing the Proposed Action, as compared to current emissions, which are classified as the baseline emissions for the purpose of this analysis. The net change is then compared to screening thresholds to assess compliance. The baseline emissions are defined as the emissions estimated for the Preferred Alternative in the Hawaii-Southern California Training and Testing Final Environmental Impact Statement/Overseas Environmental Impact Statement (U.S. Department of the Navy, 2013). Emissions of criteria air pollutants may affect human health directly by degrading local or regional air quality or indirectly by their effects on the environment. Air pollutant emissions may also have a regulatory effect separate from their physical effect, if additional air pollutant emissions change the attainment status of an air quality control region.

The estimate of criteria air pollutant emissions for each alternative is categorized by region (e.g., by range complex or testing range) so that differences in background air quality, atmospheric circulation patterns, regulatory requirements, and sensitive receptors can be addressed. An overall estimate of air pollutant emissions for Navy training and testing activities in the Study Area under each alternative is provided. Under Alternative 1, emissions were based on the average number of training and testing activities anticipated, based on the prior 6 years of data. Under Alternative 2, emissions were based on the anticipated maximum number of training and testing activities. For vessel operations, the maximum was based on the operations that occurred in 2010 the year of the highest number of operations in the range 2010–2015. While this represented the year of most total operations, the number of operations involving specific vessels in the individual operational areas may or may not have been higher than the average number used in Alternative 1. These individual variances do not change the overall result of greater total operations when accounting for all vessels in all regions under Alternative 2.

3.1.3.1.1 Impacts from Criteria Pollutants Under Alternative 1

Table 3.1-3 presents the total estimated emission results under Alternative 1 within the Study Area and includes all emissions generated, regardless of proximity to the coastline. The majority of these emissions occur beyond state waters, with the majority of emissions in most areas occurring beyond the state water boundaries.

Table 3.1-3: Annual Criteria Air Pollutant Emissions from Training and Testing Activities Occurring within the HSTT Study Area, Alternative 1

Scenario	*Emissions by Air Pollutant (TPY)*					
	CO	*NO_X*	*VOC*	*SO_X*	*PM_{10}*	*$PM_{2.5}$*
Total Emissions from all Sources	2,036	8,762	802	2,873	378	378
Baseline	1,945	8,726	804	2,885	360	360
Net Increase (Decrease)	91	36	(2)	(12)	18	18

Notes: CO = carbon monoxide, NO_x = oxides of nitrogen, VOC = volatile organic compounds, SO_x = sulfur oxides, PM_{10} = particulate matter less than or equal to 10 microns in aerodynamic diameter, $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns in aerodynamic diameter, tpy = tons per year

A significant portion of the Study Area activities will occur well offshore. While pollutants emitted in the Study Area under Alternative 1 may at times be carried ashore by winds, most training and testing activities would occur more than 12 NM offshore, and natural mixing would substantially disperse pollutants before they reach the coastal land mass. The contributions of air pollutants generated in the Study Area to the air quality in onshore areas are unlikely to measurably add to existing onshore pollutant concentrations because of the distances these offshore pollutants would be transported and their substantial dispersion during transport. In addition, the total quantity of criteria pollutants is very small in relation to the vastness of the study area. When using the Prevention of Significance Deterioration major emitting facility numbers as screening thresholds, any relevant increases are well below the thresholds. Therefore, no significant impacts on air quality as a result of criteria pollutants emissions from activities beyond territorial activities would occur.

In addition to the activities occurring beyond territorial waters, there would be activities closer to shore and these were evaluated to assess local onshore impacts. Emissions within 3 NM of shore are within the area of influence for onshore areas, and therefore have the potential to affect air quality onshore. The subsections that follow evaluate the nearshore emissions within regional areas that include attainment, nonattainment, or maintenance areas. Nearshore is defined as within 3 NM from shore. This is based on the definition of State waters and is the area within which emissions would be most likely to migrate onshore due to proximity. The emissions within 3 NM of the attainment and nonattainment/ maintenance areas are compared with baseline emissions currently occurring within 3 NM of these areas. The net emissions associated with the Proposed Action are then compared to the General Conformity *de minimis* thresholds for nonattainment/maintenance areas, or with the Prevention of Significant Deterioration thresholds for attainment areas, used as screening level analysis for potential significant environmental impact.

3.1.3.1.1.1 Impacts from Criteria Pollutants Under Alternative 1 in the State of Hawaii

As discussed in Section 3.1.2.2.1 (Hawaii) above, the State of Hawaii is classified as attainment for all criteria pollutants under the National Ambient Air Quality Standards.

Table 3.1-4 presents the estimated nearshore emissions under Alternative 1 as compared with baseline nearshore emissions. The net emissions increases are compared with the Prevention of Significant Deterioration Major Emitting Facility threshold.

The air pollutants expected to be emitted under Alternative 1 would not have a measurable impact on air quality in Hawaii waters or adjacent land areas because of the distances from land at which the pollutants are emitted and the generally strong ventilation resulting from regional meteorological conditions. Air pollutant emissions under Alternative 1 would not result in violations of state or federal air quality standards because they would not have a measurable impact on air quality in land areas. Relative to the baseline, the net emissions associated with Alternative 1 for all pollutants are well below the Prevention of Significant Deterioration Thresholds.

Table 3.1-4: Estimated Net Change in Annual Air Pollutant Emissions from Training and Testing Activities in the State of Hawaii (Within 3 NM), Alternative 1[1]

Source	*Emissions by Air Pollutant (TPY)*					
	CO	*NO_X*	*VOC*	*SO_X*	*PM_{10}*	*$PM_{2.5}$*
Total Emissions from all Sources	18	58	3	18	9	9
Baseline	25	60	3	19	6	6
Net Increase (Decrease)	(7)	(2)	0	(1)	3	3
Prevention of Significant Deterioration Threshold	250	250	250	250	250	250

[1] Table includes criteria pollutant precursors (e.g., volatile organic compounds). Individual values may not add exactly to total values due to rounding.

Notes: CO = carbon monoxide, NO_X = nitrogen oxides, $PM_{2.5}$ = particulate matter ≤ 2.5 microns in diameter, PM_{10} = particulate matter≤ 10 microns in diameter, SO_X = sulfur oxides, TPY = tons per year, VOC = volatile organic compounds

3.1.3.1.1.2 Impacts from Criteria Pollutants Under Alternative 1 in the South Coast Air Basin

As discussed in Section 3.1.2.2.2.1 (South Coast Air Basin) above, the South Coast Air Basin is classified as an extreme non-attainment area for ozone (eight-hour average concentration) under the National Ambient Air Quality Standards, a carbon monoxide maintenance area, a maintenance area for nitrogen dioxide, a maintenance area for particulate matter with a diameter less than or equal to 10 microns, and a serious non-attainment area for particulate matter with a diameter less than or equal to 2.5 microns.

Table 3.1-5 presents the estimated nearshore emissions under Alternative 1 as compared with baseline nearshore emissions. The net emissions increases are compared with the applicable General Conformity Rule *de minimis* thresholds.

The air pollutants expected to be emitted under Alternative 1 would not have a measurable impact on air quality in the South Coast Air Basin water or adjacent land areas because of the distances from land at which the pollutants are emitted and the generally strong ventilation resulting from regional meteorological conditions. Air pollutant emissions under Alternative 1 would not result in violations of state or federal air quality standards because they would not have a measurable impact on air quality in land areas. Relative to the baseline, the net emissions associated with Alternative 1 would result in a decrease in emissions within the South Coast Air Basin for all pollutants except volatile organic compounds. The increase in volatile organic compounds is below the *de minimis* emission level of 10 tons per year. As shown in Table 3.1-5, the emissions are below the applicable *de minimis* levels. A Conformity Determination is not required, and a Record of Non-Applicability (Appendix C) has been prepared.

Table 3.1-5: Estimated Net Change in Annual Air Pollutant Emissions from Training and Testing Activities in the South Coast Air Basin (Within 3 NM), Alternative 1[1]

Source	*Emissions by Air Pollutant (TPY)*					
	CO	*NO_X*	*VOC*	*SO_X*	*PM_{10}*	*$PM_{2.5}$*
Total Emissions from all Sources	73	104	28	22	19	19
Baseline	99	158	23	34	22	22
Net Increase (Decrease)	(26)	(54)	5	(12)	(3)	(3)
De Minimis Threshold	100	10	10	70	100	70

[1] Table includes criteria pollutant precursors (e.g., VOC). Individual values may not add exactly to total values due to rounding.
Notes: CO = carbon monoxide, NO_X = nitrogen oxides, $PM_{2.5}$ = particulate matter ≤ 2.5 microns in diameter, PM_{10} = particulate matter≤ 10 microns in diameter, SO_X = sulfur oxides (precursor to $PM_{2.5}$), TPY = tons per year, VOC = volatile organic compounds

3.1.3.1.1.3 Impacts from Criteria Pollutants Under Alternative 1 in the San Diego Air Basin

As discussed in Section 3.1.2.2.2.2 (San Diego Air Basin) above, the San Diego Air Basin is classified as non-attainment area for ozone (eight-hour average concentration) under the National Ambient Air Quality Standards and as a maintenance area for carbon monoxide. Effective June 3, 2016, the San Diego Air Basin was reclassified to a Moderate nonattainment area by USEPA (final approval May 4, 2016, 81 Federal Register 26697).

Table 3.1-6 presents the estimated nearshore emissions under Alternative 1 as compared with baseline nearshore emissions. The net emissions increases are compared with the applicable General Conformity Rule *de minimis* thresholds.

The air pollutants expected to be emitted under Alternative 1 would not have a measurable impact on air quality in the San Diego Air Basin water or adjacent land areas because of the distances from land at which the pollutants are emitted and the generally strong ventilation resulting from regional meteorological conditions. Air pollutant emissions under Alternative 1 would not result in violations of state or federal air quality standards because they would not have a measurable impact on air quality in land areas. Relative to the baseline, the net emissions associated with Alternative 1 would result in a decrease in emissions within the San Diego Air Basin for all nonattainment pollutants (carbon dioxide, nitrogen oxides, and volatile organic compounds). As shown in Table 3.1-6, the emissions are below the applicable *de minimis* levels, which are being used as thresholds of potential significance. A Conformity Determination is not required, and a Record of Non-Applicability (Appendix C) has been prepared.

Table 3.1-6: Estimated Net Change in Annual Air Pollutant Emissions from Training and Testing Activities in the San Diego Air Basin (Within 3 NM), Alternative 1[1]

Source	*Emissions by Air Pollutant (TPY)*					
	CO	*NO_X*	*VOC*	*SO_X*	*PM_{10}*	*$PM_{2.5}$*
Total Emissions from all Sources	138	835	445	330	39	39
Baseline	146	855	456	332	39	39
Net Increase (Decrease)	(8)	(20)	(11)	(2)	0	0
De Minimis Threshold	100	100	100	N/A	N/A	N/A

[1] Table includes criteria pollutant precursors (e.g., volatile organic compounds). Individual values may not add exactly to total values due to rounding.
Notes: CO = carbon monoxide, NO_X = nitrogen oxides, $PM_{2.5}$ = particulate matter ≤ 2.5 microns in diameter, PM_{10} = particulate matter≤ 10 microns in diameter, SO_X = sulfur oxides, TPY = tons per year, VOC = volatile organic compounds

3.1.3.1.1.4 Summary of Impacts from Criteria Pollutants Under Alternative 1

While criteria air pollutants emitted in the Study Area over territorial waters may be transported ashore, they would not affect the attainment status of the relevant air quality control regions. The amounts of air pollutants emitted in the Study Area and subsequently transported ashore would be insignificant because (1) emissions from Navy training and testing activities are small compared to the amounts of air pollutants emitted by sources ashore, (2) the distances the air pollutants would be transported are often large, and (3) the pollutants are substantially dispersed during transport. The criteria air pollutants emitted over non-territorial waters within the Study Area would be dispersed over vast areas of open ocean and thus would not have a measurable impact on environmental resources in those areas. Net emission increases within the attainment and nonattainment/maintenance areas in the Study Area are below the Prevention of Significant Deterioration and applicable General Conformity Rule *de minimis* thresholds, respectively. The Prevention of Significance Deterioration thresholds have been used as a surrogate in absence of any defined threshold to evaluate the potential for an adverse impact in attainment areas. Therefore, no significant impacts on air quality as a result of criteria pollutants over territorial waters would occur; and no significant harm to air quality as a result of criteria pollutants over non-territorial waters would occur.

3.1.3.1.2 Impacts from Criteria Pollutants Under Alternative 2

Table 3.1-7 presents the total estimated emission results under Alternative 2 within the Study Area and includes all emissions generated, regardless of proximity to the coastline. The majority of these emissions occur beyond state waters, with the majority of emissions in most areas occurring beyond the state water boundaries.

A significant portion of the Study Area activities will occur well offshore. While pollutants emitted in the Study Area under Alternative 2 may at times be carried ashore by winds, most training and testing activities would occur more than 12 nm offshore, and natural mixing would substantially disperse pollutants before they reach the coastal land mass. The contributions of air pollutants generated in the Study Area to the air quality in onshore areas are unlikely to measurably add to existing onshore pollutant concentrations because of the distances these offshore pollutants would be transported and their substantial dispersion during transport. Therefore, no significant impacts on air quality as a result of criteria pollutants emissions from activities beyond territorial activities would occur.

Table 3.1-7: Annual Criteria Air Pollutant Emissions from Training and Testing Activities Occurring Within the HSTT Study Area, Alternative 2

Scenario	*Emissions by Air Pollutant (TPY)*					
	CO	*NO_X*	*VOC*	*SO_X*	*PM_{10}*	*$PM_{2.5}$*
Total Emissions from all Sources	2,610	9,497	845	3,783	447	447
Baseline	1,945	8,726	804	2,885	360	360
Net Increase (Decrease)	665	771	41	898	87	87

Notes: CO = carbon monoxide, NO_x = oxides of nitrogen, VOC = volatile organic compounds, SO_x = sulfur oxides, PM_{10} = particulate matter less than or equal to 10 microns in aerodynamic diameter, $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns in aerodynamic diameter, tpy = tons per year

In addition to the activities occurring beyond territorial waters, there would be activities closer to shore and these were evaluated to assess local onshore impacts. Emissions within 3 NM of shore are within the area of influence for onshore areas, and therefore have the potential to affect air quality onshore. The subsections that follow evaluate the nearshore emissions within regional areas that include attainment, nonattainment, or maintenance areas. Nearshore is defined as within 3 NM from shore. This is based on the definition of State waters and is the area within which emissions would be most likely to migrate onshore due to proximity. The emissions within 3 NM of the attainment and nonattainment/maintenance areas are compared with baseline emissions currently occurring within 3 NM of these areas. The net emissions associated with Alternative 2 are then compared to the General Conformity *de minimis* thresholds for nonattainment/maintenance areas, or the Prevention of Significant Deterioration Major Emitting Facility threshold for attainment areas. For NEPA analysis purposes these are screening thresholds of potential significance.

3.1.3.1.2.1 Impacts from Criteria Pollutants Under Alternative 2 in the State of Hawaii

As discussed in Section 3.1.2.2.1 (Hawaii) above, the State of Hawaii is classified as an attainment area for all criteria pollutants under the National Ambient Air Quality Standards.

Table 3.1-8 presents the estimated nearshore emissions under Alternative 2 as compared with baseline nearshore emissions. The net emissions increases are compared with the Prevention of Significant Deterioration Major Emitting Facility threshold that is being used to ascertain potential significance.

The air pollutants expected to be emitted under Alternative 2 would not have a measurable impact on air quality in Hawaii waters or adjacent land areas because of the distances from land at which the pollutants are emitted and the generally strong ventilation resulting from regional meteorological conditions. Air pollutant emissions under Alternative 2 would not result in violations of state or federal air quality standards because they would not have a measurable impact on air quality in land areas. Relative to the baseline, the net emissions associated with Alternative 2 for all pollutants are well below the Prevention of Significant Deterioration Thresholds.

Table 3.1-8: Estimated Net Change in Annual Air Pollutant Emissions from Training and Testing Activities in the State of Hawaii (Within 3 NM), Alternative 2[1]

Source	*Emissions by Air Pollutant (TPY)*					
	CO	*NO_X*	*VOC*	*SO_X*	*PM_{10}*	*$PM_{2.5}$*
Total Emissions from all Sources	20	75	3	26	9	9
Baseline	25	60	3	19	6	6
Net Increase (Decrease)	(5)	15	0	7	3	3
Prevention of Significant Deterioration Threshold	250	250	250	250	250	250

[1] Table includes criteria pollutant precursors (e.g., volatile organic compounds). Individual values may not add exactly to total values due to rounding.
Notes: CO = carbon monoxide, NO_X = nitrogen oxides, $PM_{2.5}$ = particulate matter ≤ 2.5 microns in diameter, PM_{10} = particulate matter≤ 10 microns in diameter, SO_X = sulfur oxides, TPY = tons per year, VOC = volatile organic compounds

3.1.3.1.2.2 Impacts from Criteria Pollutants Under Alternative 2 in the South Coast Air Basin

As discussed in Section 3.1.2.2.2.1 (South Coast Air Basin) above, the South Coast Air Basin is classified as an extreme non-attainment area for ozone (eight-hour average concentration) under the National Ambient Air Quality Standards, a carbon monoxide maintenance area, a maintenance area for nitrogen dioxide, a maintenance area for particulate matter with a diameter less than or equal to 10 microns, and a serious non-attainment area for particulate matter with a diameter less than or equal to 2.5 microns.

Table 3.1-9 presents the estimated nearshore emissions under Alternative 2 as compared with baseline nearshore emissions. The net emissions increases are compared with the applicable General Conformity Rule *de minimis* thresholds.

Table 3.1-9: Estimated Net Change in Annual Air Pollutant Emissions from Training and Testing Activities in the South Coast Air Basin (Within 3 NM) Versus Baseline Emissions, Alternative 2[1]

Scenario	*Emissions by Air Pollutant (TPY)*					
	CO	*NO_X*	*VOC*	*SO_X*	*PM_{10}*	*$PM_{2.5}$*
Total Emissions from all Sources	73	104	28	22	20	20
Baseline	99	158	23	34	22	22
Net Increase (Decrease)	(26)	(54)	5	(12)	(2)	(2)
De Minimis Threshold	100	10	10	70	100	70

[1] Table includes criteria pollutant precursors (e.g., VOC). Individual values may not add exactly to total values due to rounding.
Notes: CO = carbon monoxide, NO_X = nitrogen oxides, $PM_{2.5}$ = particulate matter ≤ 2.5 microns in diameter, PM_{10} = particulate matter≤ 10 microns in diameter, SO_X = sulfur oxides (precursor of $PM_{2.5}$), TPY = tons per year, VOC = volatile organic compounds

The air pollutants expected to be emitted under Alternative 2 would not have a measurable impact on air quality in the South Coast Air Basin water or adjacent land areas because of the distances from land at which the pollutants are emitted and the generally strong ventilation resulting from regional meteorological conditions. Air pollutant emissions under Alternative 2 would not result in violations of state or federal air quality standards because they would not have a measurable impact on air quality in land areas. Relative to the baseline, the net emissions associated with Alternative 2 would result in a decrease in emissions within the South Coast Air Basin for all pollutants except volatile organic compounds. The increase in volatile organic compounds is below the *de minimis* emission level of 10 tons per year.

3.1.3.1.2.3 Impacts from Criteria Pollutants Under Alternative 2 in the San Diego Air Basin

As discussed in Section 3.1.2.2.2.2 (San Diego Air Basin) above, the San Diego Air Basin is classified as a non-attainment area for ozone (eight-hour average concentration) under the National Ambient Air Quality Standards and as a maintenance area for carbon monoxide. The USEPA designated San Diego County as a “moderate” ozone nonattainment area under the 2008 eight-hour ozone standard.

Table 3.1-10 presents the estimated nearshore emissions under Alternative 2 as compared with baseline nearshore emissions. The net emissions increases are compared with the applicable General Conformity Rule *de minimis* thresholds.

Table 3.1-10: Estimated Net Change in Annual Air Pollutant Emissions from Training and Testing Activities in the San Diego Air Basin (Within 3 NM), Alternative 2[1]

Source	*Emissions by Air Pollutant (TPY)*					
	CO	*NO_X*	*VOC*	*SO_X*	*PM_{10}*	*$PM_{2.5}$*
Total Emissions from all Sources	139	849	445	340	40	40
Baseline	146	855	456	332	39	39
Net Increase (Decrease)	(7)	(6)	(11)	8	1	1
De Minimis Threshold	100	100	100	N/A	N/A	N/A

[1] Table includes criteria pollutant precursors (e.g., volatile organic compounds). Individual values may not add exactly to total values due to rounding.
Notes: CO = carbon monoxide, NO_X = nitrogen oxides, $PM_{2.5}$ = particulate matter ≤ 2.5 microns in diameter, PM_{10} = particulate matter≤ 10 microns in diameter, SO_X = sulfur oxides, TPY = tons per year, VOC = volatile organic compounds

The air pollutants expected to be emitted under Alternative 2 would not have a measurable impact on air quality in the San Diego Air Basin water or adjacent land areas because of the distances from land at which the pollutants are emitted and the generally strong ventilation resulting from regional meteorological conditions. Air pollutant emissions under Alternative 2 would not result in violations of state or federal air quality standards because they would not have a measurable impact on air quality in land areas. Relative to the baseline, the net emissions associated with Alternative 2 would result in a decrease in emissions within the San Diego Air Basin for all nonattainment pollutants (carbon dioxide, nitrogen oxides, and volatile organic compounds).

3.1.3.1.2.4 Summary of Impacts from Criteria Pollutants Under Alternative 2

While criteria air pollutants emitted in the Study Area over territorial waters may be transported ashore, they would not affect the attainment status of the relevant air quality control regions. The amounts of air pollutants emitted in the Study Area and subsequently transported ashore would be insignificant because (1) emissions from Navy training and testing activities are small compared to the amounts of air pollutants emitted by sources ashore, (2) the distances the air pollutants would be transported are often large, and (3) the pollutants are substantially dispersed during transport. The criteria air pollutants emitted over non-territorial waters within the Study Area would be dispersed over vast areas of open ocean and thus would not have a measurable impact on environmental resources in those areas. Net emission increases within the attainment and nonattainment/maintenance areas in the Study Area are below the Prevention of Significant Deterioration and applicable General Conformity Rule *de minimis* thresholds, respectively. The Prevention of Significance Deterioration thresholds have been used as a surrogate in the absence of any defined threshold in order to evaluate the potential for an adverse impact in attainment areas. Although the increase in pollutants exceeds major emitting facility level screening criteria, they do so by factors of two to four, which is very small when spread over hundreds of thousands to millions of square nautical miles (see Chapter 2, Description of Proposed Action and Alternatives). As noted earlier, these thresholds are derived from stationary source thresholds, which are applicable to individual land installations that are orders of magnitude smaller than the study area. Therefore, no significant impacts on air quality as a result of criteria pollutants over territorial waters would occur; and no significant harm to air quality as a result of criteria pollutants over non-territorial waters would occur.

3.1.3.1.3 Impacts from Criteria Pollutants Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Discontinuing training and testing activities in the Study Area under the No Action Alternative would not measurably improve air quality in the Study Area.

3.1.3.2 Greenhouse Gases and Climate Change

Activities conducted as part of the Proposed Action would involve mobile sources using fossil fuel combustion as a source of power. Additionally, the expenditure of munitions could generate greenhouse gas emissions. Greenhouse emissions, depending on type, can persist in the atmosphere for extended periods of time, from 12 years for methane to up to 200 years for carbon dioxide. While the emissions generated by testing and training activities alone would not be enough to cause global warming, in combination with past and future emissions from all other sources they would contribute incrementally to the global warming that produces the adverse effects of climate change.

Greenhouse gas emissions were calculated using emissions factors provided by the U.S. Navy for aircraft and vessels, and published by the USEPA for munitions. Greenhouse gas emissions are summarized in Table 3.1-11. Baseline greenhouse gas emissions (i.e., emissions from existing activities) are also presented in the table.

Table 3.1-11: Greenhouse Gas Emissions from Ship and Aircraft Training and Testing Activities in the Hawaii-Southern California Training and Testing Study Area

Alternative	***Annual CO_2-Equivalent Emissions CO_2 Eq. (in Metric Tons/Year)***
Baseline	1,289,56
Alternative 1	1,384,049
Increase in emissions for Alternative 1 compared to Baseline	94,488
Alternative 2	1,655,324
Increase in emissions for Alternative 2 compared to Baseline	365,763

Note: CO_2 Eq. = carbon dioxide equivalent

Ship and aircraft greenhouse gas emissions are compared to U.S. 2014 greenhouse gas emissions in Table 3.1-12. The estimated baseline carbon dioxide equivalent emissions are 0.0187 percent of the total carbon dioxide equivalent emissions generated by the United States in 2014. The estimated carbon dioxide equivalents emissions from Alternatives 1 and 2 would increase because of increased training and testing activities to about 0.0201 and 0.0241 percent, respectively, of the total carbon dioxide equivalents emissions generated by the United States in 2014.

Table 3.1-12: Comparison of Ship and Aircraft Greenhouse Gas Emissions to United States 2014 Greenhouse Gas Emissions

Alternative	*Annual Greenhouse Gas Emissions (Metric Tons CO_2 Eq.)*	*Percentage of U.S. 2014 Greenhouse Gas Emissions*
Baseline	1,289,561	0.0187%
Alternative 1	1,384,049	0.0201%
Alternative 2	1,655,324	0.0241%
U.S. 2014 greenhouse gas emissions	6,870,500,000	

Source: U.S. Environmental Protection Agency (2016c)
Note: CO_2 Eq. = carbon dioxide equivalent

3.1.4 Summary of Potential Impacts on Air Quality

In this analysis, criteria air pollutant and greenhouse gas emissions estimates were calculated for vessels, aircraft, and munitions. For each alternative, emissions estimates were developed by range complex and other training or testing locations and totaled for the Study Area. Details of the emission estimates are provided in Appendix C (Air Quality Emissions Calculations and Record of Non-Applicability). Hazardous air pollutants were analyzed qualitatively in relation to the type and prevalence of the sources emitting hazardous air pollutants during training and testing activities.

3.1.4.1 Combined Impacts of All Stressors Under Alternative 1

As discussed in Sections 3.1.3.1 (Criteria Air Pollutants), emissions associated with Study Area training and testing under Alternative 1 primarily occur at least 3 NM offshore, and mainly occur beyond 12 NM, with the exception of amphibious operations occurring near shore. For fixed-wing aircraft activities, emissions typically occur above the 3,000 ft. mixing layer. Given these characteristics, the impacts on air quality from the combination of these resource stressors are expected to be similar to the impacts on air quality for any of these stressors taken individually without any additive, synergistic, or antagonistic interaction. Emissions of criteria pollutants are expected to increase under Alternative 1 in comparison to the baseline emissions due to increases in training and testing activity levels, but by amounts below relevant screening thresholds. Within state waters, a comparison of estimated emissions under Alternative 1 to the baseline indicates that some pollutant emissions would be reduced and others would increase. Emissions of volatile organic compounds would undergo a small increase within the South Coast Air Basin. The remaining emissions would decrease within both the South Coast Air Basin and the San Diego Air Basin. Any increases within state waters would be below relevant screening thresholds.

3.1.4.2 Combined Impacts of All Stressors Under Alternative 2

As discussed in Sections 3.1.3.1 (Criteria Air Pollutants), emissions associated with Study Area training and testing under Alternative 2 primarily occur at least 3 NM offshore, and mainly occur beyond 12 NM, with the exception of amphibious operations occurring near shore. For fixed-wing aircraft activities, emissions typically occur above the 3,000 ft. mixing layer. Given these characteristics, the impacts on air quality from the combination of these resource stressors are expected to be similar to the impacts on air quality for any of these stressors taken individually without any additive, synergistic, or antagonistic interaction. Emissions of criteria pollutants are expected to increase under Alternative 2 in comparison to the baseline emissions due to increases in training and testing activity levels. Although total increases would exceed screening thresholds, the amount would not be significant in comparison to the vast areas potentially affected. Within state waters, a comparison of estimated emissions under Alternative 2 to the baseline indicates that some pollutant emissions would be reduced and others would increase. Emissions of volatile organic compounds would undergo a small increase within the South Coast Air Basin. Emissions of sulfur dioxide and particulate matter would undergo a small increase within the San Diego Air Basin. The remaining emissions would decrease within both the South Coast Air Basin and the San Diego Air Basin. Within state waters any emissions increases are below relevant screening thresholds.

3.1.4.3 Combined Impacts of All Stressors Under the No Action Alternative

As discussed in Sections 3.1.3.1 (Criteria Air Pollutants), under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Discontinuing training and testing activities under the No Action Alternative would not measurably improve air quality in the Study Area.

REFERENCES

Arfsten, D. P., C. L. Wilson, and B. J. Spargo. (2001). Human environmental health issues related to use of radio frequency chaff. *Navy Medicine, 92*(5), 12–16.

Hawaii Department of Health. (2016). *State of Hawaii Annual Summary, 2015 Air Quality Data*. Retrieved from https://health.hawaii.gov/cab/files/2016/12/aqbook_2015.pdf.

Intergovernmental Panel on Climate Change. (2014). *IPCC Fifth Assessment Report*. Geneva, Switzerland: Intergovernmental Panel on Climate Change.

National Oceanic and Atmospheric Administration. (2017). *National Data Buoy Center*. Retrieved from http://www.ndbc.noaa.gov/obs.shtml.

Spargo, B. J., T. L. Hullar, S. L. Fales, H. F. Hemond, P. Koutrakis, W. H. Schlesinger, and J. G. Watson. (1999). *Environmental Effects of RF Chaff*. Washington, DC: Naval Research Laboratory.

U.S. Department of Defense. (2014). *2014 Climate Change Adaptation Roadmap*. Alexandria, VA: Department of Defense.

U.S. Department of the Navy. (2007). *Draft Supplemental Enivronmental Impact Statement for the Introduction of F/A-18 E/F (Super Hornet) Aircraft to the East Coast of the United States*. Washington, DC.

U.S. Department of the Navy. (2009). *Final Environmental Assessment Transition of E-2C Hawkeye to E-2D Advanced Hawkeye at Naval Station Norfolk, Virginia and Naval Base Ventura County Point Mugu, California*. Washington, DC.

U.S. Department of the Navy. (2010). *United States Marine Corps F-35B East Coast Basing Environmental Impact Statement*. Norfolk, VA: Naval Facilities Engineering Command, Mid-Atlantic.

U.S. Department of the Navy. (2013). *Navy Guidance for Compliance with the Clean Air Act General Conformity Rule*. Washington, DC: Office of the Chief of Naval Operations Energy and Environmental Readiness Division.

U.S. Department of the Navy. (2014). *Final Supplemental Environmental Impact Statement for the Introduction of the P-8A Multi-Mission Maritime Aircraft into the U.S. Navy Fleet*. Norfolk, VA: Naval Facilities Engineering Command Atlantic.

U.S. Department of the Navy. (2017). *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III)*. San Diego, CA: Space and Naval Warfare System Command, Pacific.

U.S. Environmental Protection Agency. (1972). *Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States*. Research Triangle Park, NC: Environmental Protection Agency Office of Air Programs.

U.S. Environmental Protection Agency. (1992). *Procedures for Emission Inventory Preparation*. (EPA420-R-92-009). Washington, DC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. (2007a). *8-hour ozone nonattainment areas in New England*. Retrieved from http://www.epa.gov/region1/airquality/nattainm.html.

U.S. Environmental Protection Agency. (2007b). *The Plain English Guide to the Clean Air Act*. (EPA-456/K-07-001). Research Triangle Park, NC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. (2008a). *Toxicity Characteristic Leaching Procedure (TCLP) for VOCs, SVOCs, Chlorinated Pesticides and Herbicides, and Metals by SW-846 Method 1311 and Analysis*. Washington, DC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. (2008b). Chapter 15: Ordnance Detonation *AP 42* (5th ed., Vol. 1).

U.S. Environmental Protection Agency. (2009a). Chapter 15: Ordnance Detonation *AP 42* (5th ed., Vol. 1).

U.S. Environmental Protection Agency. (2009b). *Technical support document for endangerment and cause or contribute findings for greenhouse gases under Section 202(a) of the Clean Air Act*. Washington, DC: Council on Foreign Relations.

U.S. Environmental Protection Agency. (2009c). *Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act*. Washington, DC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. (2010). Self-Regulatory Organizations; NYSE Amex LLC; Notice of Filing of Amendment Nos. 2 and 3, and Order Granting Accelerated Approval to a Proposed Rule Change as Modified by Amendment Nos. 1, 2, and 3 Thereto, To Adopt as a Pilot Program a New Rule Series for the Trading of Securities Listed on the NASDAQ Stock Market Pursuant to Unlisted Trading Privileges, and Amending Existing NYSE Amex Equities Rules as Needed To Accommodate the Trading of NASDAQ Listed Securities on the Exchange. *Federal Register, 75*(135), 17274.

U.S. Environmental Protection Agency. (2015). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013*. Washington, DC: U.S. Environmental Protection Agency. Retrieved from http://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2015-Main-Text.pdf.

U.S. Environmental Protection Agency. (2016a). *Hazardous Air Pollutants*. Retrieved from http://www.epa.gov/haps.

U.S. Environmental Protection Agency. (2016b). *National Ambient Air Quality Standards*. Retrieved from https://www.epa.gov/criteria-air-pollutants/naaqs-table.

U.S. Environmental Protection Agency. (2016c). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014*. Washington, DC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. (2017). *Nonattainment Areas for Criteria Pollutants (Green Book)*. Retrieved from https://www.epa.gov/green-book.

United Nations Framework Convention on Climate Change. (2013). *Revision of the UNFCCC Reporting Guidelines on Annual Inventories for Parties included in Annex I to the Convention (Following Incorporation of the Provisions of Decision 24/CP.19)*. (FCCC/CP/2013/10/Add.3).

Western Regional Climate Center. (2016a). *Hawaii climate*. Retrieved from http://www.wrcc.dri.edu/narratives/HAWAII.htm.

Western Regional Climate Center. (2016b). *Comparative Precipitation – Largest U.S. Cities*. Retrieved from http://www.wrcc.dri.edu/climate-summaries/.

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3.2 Sediments and Water Quality

PREFERRED ALTERNATIVE SYNOPSIS

The United States Department of the Navy considered all potential stressors that sediments and water quality could potentially be exposed to from the Proposed Action. The following conclusions have been reached for the Preferred Alternative (Alternative 1):

- Explosives and explosives byproducts: Impacts from explosives and explosives byproducts would be short-term and local. Impacts from unconsumed explosives and constituent chemical compounds would be minimal and limited to the area adjacent to the munition. Explosives and constituent compounds could persist in the environment depending on the integrity of the undetonated munitions casing and the physical conditions on the seafloor where the munition resides. Chemical and physical changes to sediments and water quality, as measured by the concentrations of contaminants or other anthropogenic compounds, may be detectable and would be below applicable regulatory standards for determining effects on biological resources and habitats.

- Chemicals other than explosives: Impacts from other chemicals not associated with explosives would be both short term and long term depending on the chemical and the physical conditions on the seafloor where the source of the chemicals resides. Impacts would be minimal and localized to the immediate area surrounding the source of the chemical release.

- Metals: Impacts from metals would be minimal, long term, and dependent on the metal and the physical conditions on the seafloor where the metal object (e.g., non-explosive munition) resides. Impacts would be localized to the area adjacent to the metal object. Concentrations of metal contaminants near the expended material or munition may be measurable and are likely to be similar to the concentrations of metals in sediments from nearby reference locations.

- Other materials: Impacts from other expended materials not associated with munitions would be both short-term and long-term depending on the material and the physical conditions on the seafloor where the material resides. Impacts would be localized to the immediate area surrounding the material. Chemical and physical changes to sediments and water quality, as measured by the concentrations of contaminants or other anthropogenic compounds near the expended material, are not likely to be detectable and would be similar to the concentrations of chemicals and material residue from nearby reference locations.

3.2.1 Introduction and Methods

3.2.1.1 Introduction

The following sections provide an overview of the characteristics of sediments and water quality in the Hawaii-Southern California Training and Testing (HSTT) Study Area (Study Area), and describe, in general terms, the methods used to analyze potential impacts of the Proposed Action on these resources.

3.2.1.1.1 Sediments

The discussion of sediments begins with an overview of sediment sources and characteristics in the Study Area, and considers factors that have the potential to affect sediment quality.

3.2.1.1.1.1 Characteristics of Sediments

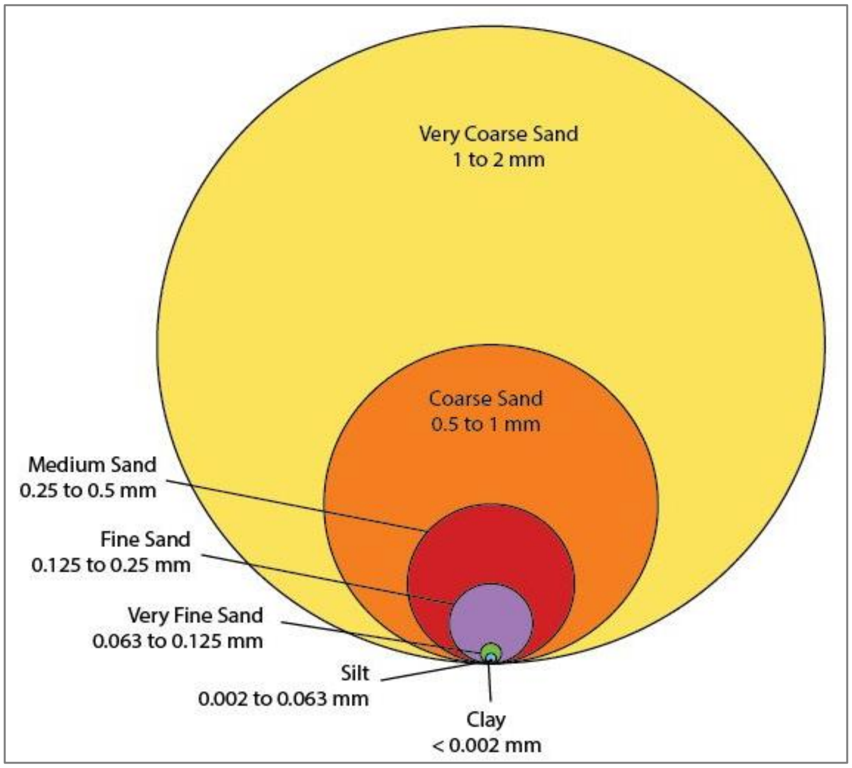

Figure 3.2-1: Sediment Particle Size Comparison

Sediments consist of solid fragments of organic and inorganic matter forming the bottom, or substrate, of bodies of water. Sediments in the marine environment (e.g., in ocean basins) are either terrigenous, meaning that they originate from land, or are biogenic (i.e., formed from the remains of marine organisms). Terrigenous sediments come from the weathering of rock and other land-based substrates and are transported by water, wind, and ice (glaciers) to the seafloor. Biogenic sediments are produced in the oceans by the skeletal remains of single-celled benthic and planktonic organisms (e.g., foraminiferans and diatoms). When an organism dies, its remains are deposited on the seafloor. The remains are composed primarily of either calcium carbonate (e.g., a shell) or silica, and mixed with clays, form either a calcareous or siliceous ooze (Chester, 2003). Sediments in the Atlantic Ocean are predominantly composed of calcareous oozes and the Pacific Ocean has more siliceous oozes (Kennett, 1982). In addition to composition, sediments are also classified by size. Blott and Pye (2012) reviewed commonly used historical classification systems and offered a refined system that is adopted for describing sediments in this section. Sediments are grouped into five size classes: boulders, gravel, sand, silt, and clay. Sands range in size from 0.063 millimeter (mm) (very fine sands) to 2 mm (very coarse sands) (Figure 3.2-1). For comparison, the thickness of a nickel is approximately 2 mm. Sediment types smaller than sands are silts (0.0020.063 mm in diameter) and clays (particles less than 0.002 mm in diameter). Sediments larger than sands are various types of gravel ranging in size from 2 mm (granules) to 64 mm (cobbles). Sediments greater than 64 mm in diameter are defined as boulders and range up to 2,048 mm (Blott & Pye, 2012; U.S. Department of Agriculture, 1993). Fine-grained silts and clays are often found mixed together in areas beyond the continental slope, such as on abyssal plains, and are referred to generally as mud (Kennett, 1982). Sediments in nearshore waters and on the continental shelf contain more sands that are primarily terrigenous, and sediments farther from shore in deep ocean basins are primarily biogenic. As organic and inorganic particles move downward through the water column and ultimately to the seafloor, many substances, including contaminants, that adhere to the particles and that are otherwise scarce in the water column become concentrated in bottom sediments (Chapman et al., 2003; Kszos et al., 2003).

3.2.1.1.1.2 Factors Affecting Marine Sediment Quality

The quality of sediments is influenced by their physical, chemical, and biological components; by where they are deposited; by the properties of seawater; and by other inputs and sources of contamination. Sediments tend to be dynamic, where factors affecting marine sediments often interact and influence each other. These factors are summarized below.

Physical characteristics and processes: At any given site, the texture and composition of sediments are important physical factors that influence the types of substances that are retained in the sediments, and subsequent biological and chemical processes. For example, clay-sized and smaller sediments and similarly sized organic particles tend to bind potential sediment contaminants and potentially limit their movement in the environment (U.S. Environmental Protection Agency, 2009). Conversely, fine-grained sediments are easily disturbed by currents and bottom-dwelling organisms, dredging, storms, and bottom trawling (Eggleton & Thomas, 2004; Hedges & Oades, 1997). Disturbance is also possible in deeper areas, where currents are minimal (Carmody et al., 1973), from mass wasting events such as underwater slides and debris flows (Coleman & Prior, 1988). If re-suspended, fine-grained sediments (and any substances bound to them) can be transported long distances.

Chemical characteristics and processes: The concentration of oxygen in sediments strongly influences sediment quality through its effect on the binding of materials to sediment particles. At the sediment surface, the level of oxygen is usually the same as that of the overlying water. Deeper sediment layers, however, are often low in oxygen (i.e., hypoxic) or have no oxygen (i.e., anoxic), and have a low oxidation-reduction potential, which predicts the stability of various compounds that regulate nutrient and metal availability in sediments. Certain substances combine in oxygen-rich environments and become less available for other chemical or biological reactions.

Biological characteristics and processes: Organic matter in sediment provides food for resident microbes. The metabolism of these microbes can change the chemical environment in sediments and thereby increase or decrease the mobility of various substances and influence the ability of sediments to retain and transform those substances (Mitsch et al., 2009; U.S. Environmental Protection Agency, 2008a). Bottom-dwelling animals often rework sediments in the process of feeding or burrowing. In this way, marine organisms influence the structure, texture, and composition of sediments, as well as, the horizontal and vertical distribution of substances in the sediment (Boudreau, 1998). Moving substances out of or into low or no-oxygen zones in the sediment may alter the form and availability of various substances. The metabolic processes of bacteria also influence sediment components directly. For example, sediment microbes may convert mercury to methyl mercury, increasing its toxicity (Mitchell & Gilmour, 2008). However, it is more common that biological processes break down contaminants and reduce toxicity in sediments (White et al., 1997).

Location: The quality of coastal and marine sediments is influenced substantially by inputs from adjacent watersheds (Turner & Rabalais, 2003). Proximity to watersheds with large cities or intensively farmed lands often increases the amount of both inorganic and organic contaminants that find their way into coastal and marine sediments. A wide variety of metals and organic substances, such as polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and pesticides—often referred to collectively as "persistent organic pollutants"—are discharged into coastal waters by urban, agricultural, and industrial point and non-point sources in the watershed (U.S. Environmental Protection Agency, 2008a). Location on the ocean floor also influences the distribution and concentration of various elements through local geology and volcanic activity (Demina & Galkin, 2009), as well as through landslides and debris flow events (Coleman & Prior, 1988).

Other Contributions to Sediments: While the greatest mass of sediments is carried into marine systems by rivers (U.S. Environmental Protection Agency, 2008a), wind and rain also deposit materials in coastal waters and contribute to the mass and quality of sediments. For example, approximately 80 percent of the mercury released by human activities comes from coal combustion, mining and smelting, and solid waste incineration (Agency for Toxic Substances and Disease Registry, 1999). These activities are generally considered to be the major sources of mercury in marine systems (Fitzgerald et al., 2007). Atmospheric deposition of lead is similar in that human activity is a major source of lead in sediments (Wu & Boyle, 1997).

3.2.1.1.2 Water Quality

The discussion of water quality begins with an overview of the characteristics of marine waters, including pH (a measure of acidity), temperature, oxygen, nutrients, salinity, and dissolved elements. The discussion then considers how those characteristics of marine waters are influenced by physical, chemical, and biological processes.

3.2.1.1.2.1 Characteristics of Marine Waters

The composition of water in the marine environment is determined by complex interactions among physical, chemical, and biological processes. Physical processes include region-wide currents and tidal flows, seasonal weather patterns and temperature, sediment characteristics, and unique local conditions, such as the volume of fresh water delivered by large rivers. Chemical processes involve salinity, pH, dissolved minerals and gases, particulates, nutrients, and pollutants. Biological processes involve the influence of living things on the physical and chemical environment. The two dominant biological processes in the ocean are photosynthesis and respiration, particularly by microorganisms. These processes involve the uptake, conversion, and excretion of waste products during growth, reproduction, and decomposition (Mann & Lazier, 1996).

3.2.1.1.2.2 Influences of Marine Properties and Processes on Seawater Characteristics

Ocean currents and tides mix and redistribute seawater. In doing so, they alter surface water temperatures, transport and deposit sediment, and concentrate and dilute substances that are dissolved and suspended in the water. These processes operate to varying degrees from nearshore areas to the abyssal plain. Salinity also affects the density of seawater and, therefore, its movement relative to the sea surface (Libes, 2009). Upwelling brings cold, nutrient-rich waters from deeper areas, increasing the productivity of local surface waters (Mann & Lazier, 1996). Storms and hurricanes also cause strong mixing of marine waters (Li et al., 2008).

Temperature and pH influence the behavior of trace metals in seawater, such as the extent to which they dissolve in water (i.e., the metal's solubility) or their tendency to adsorb to organic and inorganic particles. However, the degree of influence differs widely among metals (Byrne, 1996). The concentration of a given element may change with position in the water column. For example, some metals (e.g., cadmium) are present at low concentrations in surface waters and at higher concentrations at depth (Bruland, 1992), while others decline quickly with increasing depth below the surface (e.g., zinc and iron) (Morel & Price, 2003; Nozaki, 1997). On the other hand, dissolved aluminum concentrations are highest at the surface, lowest at mid-depths, and increase again at depths below about 1,000 m (Li et al., 2008).

Substances, such as nitrogen, carbon, silicon, and trace metals are extracted from the water by biological processes. Others, like oxygen and carbon dioxide, are produced by biological processes. Metabolic waste products add organic compounds to the water, and may also absorb trace metals, removing those metals from the water column. Those organic compounds may then be consumed by biological organisms, or they may aggregate with other particles and sink (Mann & Lazier, 1996; Wallace et al., 1977).

Runoff from coastal watersheds influences local and regional coastal water conditions, especially large rivers. Influences include increased sediments and pollutants, and decreased salinity (Rabalais et al., 2002; Turner & Rabalais, 2003; Wiseman & Garvine, 1995). Coastal bays and large estuaries serve to filter river outflows and reduce total discharge of runoff to the ocean (Edwards et al., 2006; Mitsch et al., 2009). Depending on their structure and components, estuaries can directly or indirectly affect coastal water quality by recycling various compounds (e.g., excess nutrients), sequestering elements in more inert forms (e.g., trace metals), or altering them, such as the conversion of mercury to methyl mercury (Mitchell & Gilmour, 2008; Mitsch & Gosselink, 2007).

3.2.1.1.2.3 Coastal Water Quality

Most water quality problems in coastal waters of the United States are from degraded water clarity or increased concentrations of phosphates or chlorophyll-*a* (U.S. Environmental Protection Agency, 2012a). Water quality indicators measured are dissolved inorganic nitrogen, dissolved inorganic phosphorus, water clarity or turbidity, dissolved oxygen, and chlorophyll-*a*. Chlorophyll-*a* is an indicator of microscopic algae (phytoplankton) abundance used to judge nutrient availability (i.e., phosphates and nitrates). Excess phytoplankton blooms can decrease water clarity and, when phytoplankton die off following blooms, lower concentrations of dissolved oxygen. Most sources of these impacts arise from on-shore point and non-point sources of pollution. Point sources are direct water discharges from a single source, such as industrial or sewage treatment plants, while non-point sources are the result of many diffuse sources, such as runoff caused by rainfall.

3.2.1.2 Methods

The following four stressors may impact sediments or water quality: (1) explosives and explosives byproducts, (2) metals, (3) chemicals other than explosives, and (4) other materials (e.g., plastics). The term "stressor" is used because the military expended materials in these four categories may affect sediments or water quality by altering their physical or chemical characteristics. The potential impacts of these stressors are evaluated based on the extent to which the release of these materials could directly or indirectly impact sediments or water quality such that existing laws or standards would be violated or recommended guidelines would be exceeded. The differences between standards and guidelines are described below.

- **Standards** are established by law or through government regulations that have the force of law. Standards may be numerical or narrative. Numerical standards set allowable concentrations of specific pollutants (e.g., micrograms per liter [µg/L]) or levels of other parameters (e.g., pH) to protect the water's designated uses. Narrative standards describe water conditions that are not acceptable.
- **Guidelines** are non-regulatory, and generally do not have the force of law. They reflect an agency's preference or suggest conditions that should prevail. Guidelines are often used to assess the condition of a resource to guide subsequent steps, such as the disposal of

dredged materials. Terms such as screening criteria, effect levels, and recommendations are also used.

3.2.1.2.1 State Standards and Guidelines

State jurisdiction regarding sediments and water quality extends from the low tide line to 3 nautical miles (NM) offshore for both California and Hawaii. Creating state-level sediments and water quality standards and guidelines begins with each state establishing a use for the water, which is referred to as its "designated" use. Examples of such uses of marine waters include fishing, shellfish harvesting, and recreation. For this section, a water body is considered "impaired" if any one of its designated uses is not met. Once this use is designated, standards or guidelines are established to protect the water at the desired level of quality. Applicable state standards and guidelines specific to each stressor are detailed in Section 3.2.3 (Environmental Consequences).

3.2.1.2.2 Federal Standards and Guidelines

Federal jurisdiction regarding sediments and water quality extends from 3 to 200 NM along the Pacific coast of the United States. These standards and guidelines are mainly the responsibility of the United States (U.S.) Environmental Protection Agency (USEPA), specifically ocean discharge provisions of the Clean Water Act (33 United States Code [U.S.C.] section 1343). Ocean discharges may not result in "unreasonable degradation of the marine environment." Specifically, disposal may not result in: (1) unacceptable negative effects on human health; (2) unacceptable negative effects on the marine ecosystem; (3) unacceptable negative persistent or permanent effects due to the particular volumes or concentrations of the dumped materials; and (4) unacceptable negative effects on the ocean for other uses as a result of direct environmental impact (40 Code of Federal Regulations [CFR] section 125.122). Applicable federal standards and guidelines specific to each stressor are detailed in Section 3.2.3 (Environmental Consequences). Proposed training and testing activities also occur beyond 200 NM. Even though Clean Water Act regulations may not apply, pertinent water quality standards are used as accepted scientific standards to assess potential impacts on sediments and water quality from the Proposed Action.

The International Convention for the Prevention of Pollution from Ships (Convention) addresses pollution generated by normal vessel operations. The Convention is incorporated into U.S. law as 33 U.S.C. sections 1901–1915. The Convention includes six annexes: Annex I, oil discharge; Annex II, hazardous liquid control; Annex III, hazardous material transport; Annex IV, sewage discharge; Annex V, plastic and garbage disposal; and Annex VI, air pollution. The U.S. Department of the Navy (Navy) is required to comply with the Convention; however, the United States is not a party to Annex IV. The discharge of sewage by military vessels is regulated by Section 312(d) of the Clean Water Act. The Convention contains handling requirements and specifies where materials can be discharged at sea, but it does not contain standards related to sediments nor water quality.

The National Defense Authorization Act of 1996 amended section 312 of the Clean Water Act, directing the USEPA and the Department of Defense to jointly establish the Uniform National Discharge Standards for discharges (other than sewage) incidental to the normal operation of military vessels. The Uniform National Discharge Standards program establishes national discharge standards for military vessels in U.S. coastal and inland waters extending seaward to 12 NM. Twenty-five types of discharges were identified as requiring some form of pollution control (e.g., a device or policy) to reduce or eliminate the potential for impacts. The discharges addressed in the program include, ballast water, deck runoff, and seawater used for cooling equipment. For a complete list of discharges refer to 40 CFR part 1700.4.

These national discharge standards reduce the environmental impacts associated with vessel discharges, stimulate the development of improved pollution control devices aboard vessels, and advance the development of environmentally sound military vessels. The U.S. Navy adheres to regulations outlined in the Uniform National Discharge Standards program, and, as such, the analysis of impacts in this Environmental Impact Statement (EIS)/Overseas EIS (OEIS) will be limited to potential impacts from training and testing activities including impacts from military expended materials, but not impacts from discharges addressed under the Convention or the Uniform National Discharge Standards program.

3.2.1.2.3 Intensity and Duration of Impact

The intensity or severity of impacts is defined as follows (listed by increasing level of impact):

- Chemical, physical, or biological changes in sediment or water quality would not be detectable as a result of the use of military materials. The proposed activities would not violate water quality standards.
- Chemical, physical, or biological changes in sediments or water quality would be measurable, but total concentrations would not violate applicable standards, regulations, and guidelines. Sediment and water quality would be equivalent to existing conditions, and designated uses of the water body or substrate would not change.
- Chemical, physical, or biological changes in sediments or water quality would be measurable and readily apparent but total concentrations would not violate applicable standards, regulations, and guidelines. Sediment or water quality would be altered compared to the historical baseline or desired conditions, and designated uses of the water body or substrate would be changed. Mitigation would be necessary and would likely be successful.
- Chemical, physical, or biological changes in sediment or water quality would be readily measurable, and some standards, regulations, and guidelines would be periodically approached, equaled, or exceeded as measured by total concentrations. Sediment or water quality would be frequently altered from the historical baseline or desired conditions, and designated uses of the water body or substrate would be changed. Mitigation measures would be necessary to limit or reduce impacts on sediment or water quality, although the efficacy of those measures would not be assured.

Duration is characterized as either short-term or long-term. Short-term is defined as days or months. Long-term is defined as months or years, depending on the type of activity or the materials involved.

3.2.1.2.4 Measurement and Prediction

Many of the conditions discussed above often influence each other, so measuring and characterizing various substances in the marine environment is often difficult (Byrne, 1996; Ho et al., 2007). For instance, sediment contaminants may also change over time. Valette-Silver (1993) reviewed several studies that demonstrated the gradual increase in a variety of contaminants in coastal sediments that began as early as the 1800s, continued into the 1900s, peaked between the 1940s and 1970s, and declined thereafter (e.g., lead, dioxin, polychlorinated biphenyls. After their initial deposition, normal physical, chemical, and biological processes can re-suspend, transport, and redeposit sediments and associated substances in areas far removed from the source (Hameedi et al., 2002; U.S. Environmental Protection Agency, 2012a). The conditions noted above further complicate predictions of the impact of various substances on the marine environment.

3.2.1.2.5 Sources of Information

Relevant literature was systematically reviewed to complete this analysis of sediments and water quality. The review included journals, technical reports published by government agencies, work conducted by private businesses and consulting firms, U.S. Department of Defense reports, operational manuals, natural resource management plans, and current and prior environmental documents for facilities and activities in the Study Area.

Because of the proximity of inshore and nearshore areas to humans, information on the condition of sediments and water quality in those areas tends to be relatively readily available. However, much less is known about deep ocean sediments and open ocean water quality. Since sediments and water quality in inshore and nearshore areas tend to be affected by various human social and economic activities, two general assumptions are used in this discussion: (1) sediments and water quality generally improve as distance from the shore increases; and (2) sediments and water quality generally improve as depth increases.

3.2.1.2.6 Areas of Analysis

The locations where specific military expended materials would be used are discussed under each stressor in Section 3.2.3 (Environmental Consequences).

3.2.2 Affected Environment

The affected environment includes sediments and water quality within the Study Area, from nearshore areas to the open ocean and deep sea bottom. Existing sediment conditions are discussed first and water quality conditions thereafter.

3.2.2.1 Sediments

The following subsections discuss sediments for each region in the Study Area. Table 3.2-1 provides the sediment quality criteria and index for the U.S. West Coast and Hawaiian Islands.

3.2.2.1.1 Sediment Quality in Nearshore and Offshore Regions of the Hawaiian Islands

The composition and distribution of bottom substrate in the Insular Pacific-Hawaiian Large Marine Ecosystem are discussed in Section 3.5 (Habitats). In the *National Coastal Condition Report IV* (U.S. Environmental Protection Agency, 2012a), estuarine and coastal ocean areas in the USEPA's Hawaii Region were rated good, fair, or poor for sediment quality, which is based on measurements of sediment contaminants and total organic carbon in sediments (no data on sediment toxicity is available for Hawaii). The USEPA rated 74 percent of coastal ocean sediments good, 8 percent fair, and 18 percent poor (Figure 3.2-2). Specifically for contaminants, 83 percent of coastal waters of the Main Hawaiian Islands were rated good, 11 percent were rated fair, and 6 percent were rated poor (U.S. Environmental Protection Agency, 2012a). The two sites receiving a poor rating were in Waimea Bay, Kauai where chromium concentrations exceeded the level where adverse effects are likely to occur in 50 percent of samples. Sampling sites in Pearl Harbor, Keehi Lagoon on Oahu, Hilo Bay on Hawaii, and other harbor areas exceeded effects levels for individual metals. For total organic carbon, 12 percent of coastal waters were rated poor and 18 percent were rated fair. Some of the same areas with relatively high concentrations of contaminants in sediments also had higher concentrations of total organic carbon, including Keehi Lagoon and Hilo Bay. Suburban development east of Honolulu contributed to higher levels of total organic carbon in adjacent coastal waters. Higher levels of total organic carbon in sediments can be an indicator of higher concentrations of chemical pollutants and poor sediment quality (U.S. Environmental Protection Agency, 2012a).

Some metals naturally occur at elevated concentrations in the volcanic soils of Hawaii. Natural concentrations of copper, zinc, nickel, and chromium are high compared to soils in the mainland United States. Pearl Harbor receives a substantial amount of metal contamination because it serves as a natural trap for sediment particles (U.S. Environmental Protection Agency, 2008b).

Table 3.2-1: Sediment Quality Criteria and Index, United States West Coast and Hawaiian Islands

Parameter	*Site Criteria*			*Regional Criteria*		
	Good	*Fair*	*Poor*	*Good*	*Fair*	*Poor*
Sediment Toxicity	Amphipod[1] survival rate ≥ 80%	n/a	Amphipod[1] survival rate < 80%	< 5% of coastal area in poor condition	n/a	≥ 5% of coastal area in poor condition
Sediment Contaminants	No ERM[2] concentration exceeded, and < 5 ERL[3] concentrations exceeded	No ERM[2] concentration exceeded and ≥ 5 ERL[3] concentrations exceeded	An ERM[2] concentration exceeded for one or more contaminants	< 5% of coastal area in poor condition	5–15% of coastal area in poor condition	> 15% of coastal area in poor condition
Excess Sediment TOC	TOC concentration < 2%	TOC concentration 2% to 5%	TOC concentration > 5%	< 20% of coastal area in poor condition	20–30% of coastal area in poor condition	> 30% of coastal area in poor condition
Sediment Quality Index	No poor ratings, sediment contaminants criteria are rated "good"	No poor ratings, sediment contaminants criteria are rated "fair"	One or more individual criteria rated poor	< 5% of coastal area in poor condition, and > 50% in good condition	5–15% of coastal area in poor condition, and > 50% in combined fair and poor condition	> 15% of coastal area in poor condition

Source: (U.S. Environmental Protection Agency, 2009, 2012a); State of California (2009)

[1]Amphipods are small animals found in a wide variety of aquatic habitats. Because they are so widely distributed, they are often used as an indicator of toxicity in sediments and water bodies.

[2]ERM (effects range-median) is the level measured in the sediment below which adverse biological effects were measured 50 percent of the time.

[3]ERL (effects range-low) is the level measured in the sediment below which adverse biological effects were measured 10 percent of the time Long et al. (1995).

Notes: % = percent. ≥ = equal to or greater than, < = less than, > = greater than, n/a = not applicable, TOC = total organic carbon

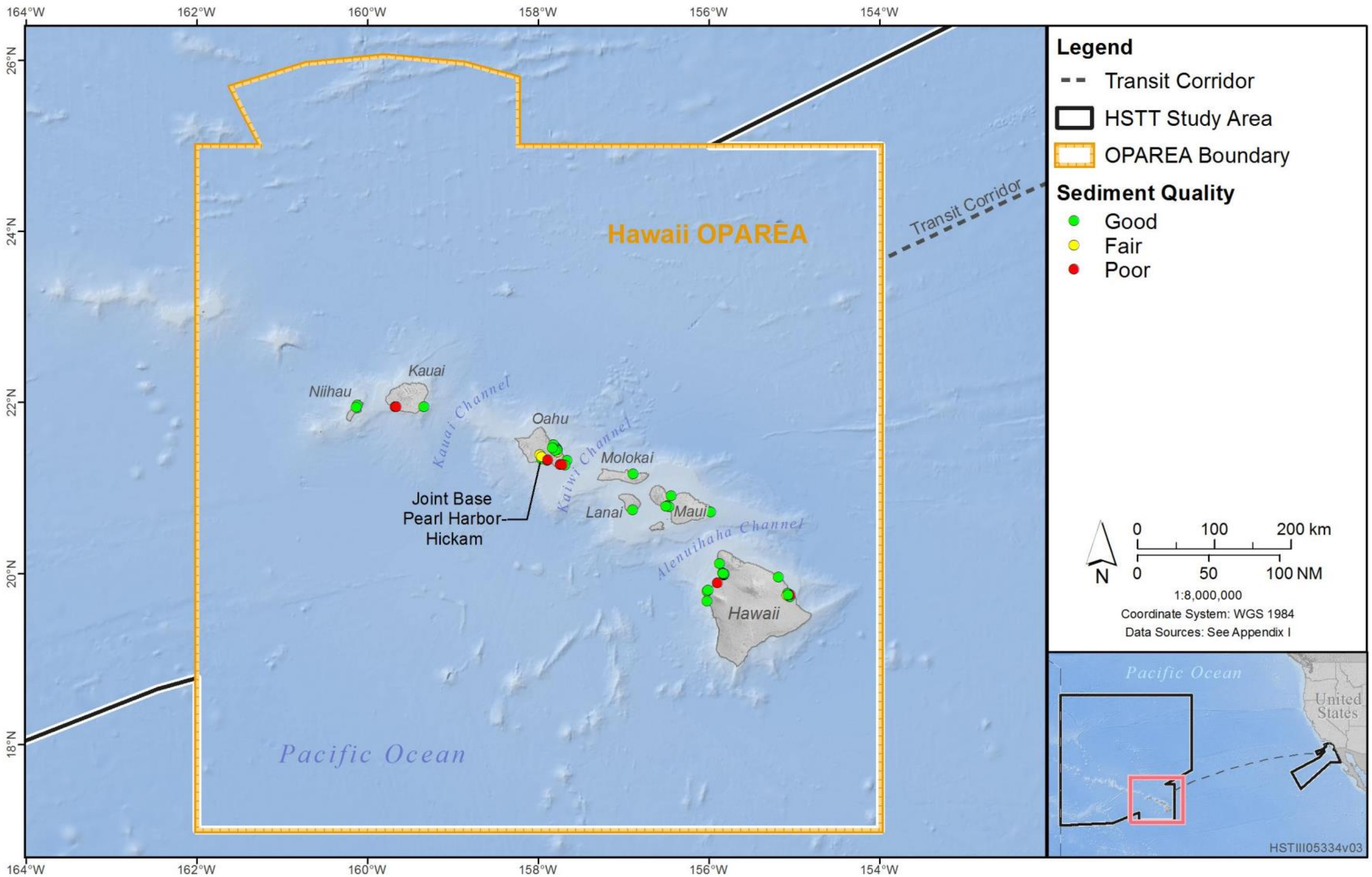

Figure 3.2-2: Sediment Quality Index for the Hawaiian Islands

Notes: HSTT = Hawaii Southern California Training and Testing, OPAREA = Operating Area

Anthropogenic activities within and around Pearl Harbor, including Navy activities and private industrial, commercial, and agricultural activities, contribute pollutants through point and non-point sources. These activities release numerous pollutants into Pearl Harbor, where sediments can act as a sink or repository for chemicals. The Department of the Navy conducted a Remedial Investigation/Feasibility Study of the sediments in Pearl Harbor from March to June 2009. The results of the Remedial Investigation indicated that eight metals (antimony, cadmium, copper, lead, mercury, selenium, silver, and zinc), total high molecular weight polycyclic aromatic hydrocarbons, total polychlorinated biphenyls, and two chlorinated pesticides (dieldrin and total endosulfan) exceeded the project screening criteria (Table 3.2-2) (U.S. Department of the Navy, 2010b). Surface weighted-average concentrations in sediment were below project screening criteria in Middle Loch and West Loch and above project screening criteria in Southeast Loch, Bishop Point, northwest shoreline of Ford Island, Aiea Bay, shoreline of Oscar 1 and 2, and off the Waiau Power Plant (U.S. Department of the Navy, 2010b).

In 2012, the Space and Naval Warfare Systems Command conducted field measurements on the resuspension of sediments from propeller wash in Department of Defense harbors, including Pearl Harbor (Wang et al., 2014a). Background concentration of contaminants were measured in sediments prior to conducting the study (Table 3.2-2). In an earlier study, (Wang et al., 2009), estimated that transiting Navy (and other military) vessels in Pearl Harbor resuspended 54 tons of sediments per day, which amounts to more than 10 percent of the sediment load from the entire Pearl Harbor watershed. Wang et al. (2014a) measured sediment resuspension and associated metal contaminants from a tugboat propeller wash at two piers, Bravo Pier and Oscar Pier in Pearl Harbor; measurements included the concentrations of the metals chromium, nickel, copper, zinc, arsenic, silver, cadmium, and lead, in the sediment plume. The concentrations of chromium and nickel were the only ones consistently above U.S. Environmental Protection Agency water quality criteria following the resuspension events (Wang et al., 2014a).

Between 65 and 90 percent of metal concentrations, depending on the metal, were in the dissolved phase, rather the particle-bound phase, contributing to greater dispersion within the harbor. The data were used as input and validation of a fate and transport model, which predicted that resuspended metals can be transported and dispersed far from the piers, and, over several days, throughout much of the harbor, potentially resulting in recontamination of remediated areas as well as increased contaminant concentrations in more remote areas of the harbor (Wang et al., 2014a).

Table 3.2-2: Sediment Screening Criteria and Background Concentrations for Pearl Harbor Sediment Remedial Investigation

Parameter		*Pier in Pearl Harbor*	*Background Concentrations (ppm)*	*Sediment Screening Criteria (mg/kg [ppm], dry weight)*
Metals	Antimony	Bravo	Not Measured	8.4
		Oscar		
	Arsenic	Bravo	13.0	27.5
		Oscar	10.5	
	Cadmium	Bravo	0.82	3.2
		Oscar	0.41	
	Chromium	Bravo	86.4	277
		Oscar	51.8	
	Copper	Bravo	97.8	214
		Oscar	49.0	
	Lead	Bravo	53.0	119
		Oscar	41.8	
	Mercury	Bravo	Not Measured	0.71
		Oscar		
	Nickel	Bravo	54.0	660
		Oscar	33.2	
	Selenium	Bravo	Not Measured	3.8
		Oscar		
	Silver	Bravo	0.67	1.8
		Oscar	0.32	
	Zinc	Bravo	290	330
		Oscar	225	
Organic Compounds	HMW-PAHs	N/A	Not Measured	35,253
	Total PCBs	Bravo/Oscar	ND	92 (> 2 m water depth) 29 (< 2 m water depth)
Pesticides	Total DDT	Bravo/Oscar	Not Measured	106.6
	Dieldrin	Bravo/Oscar	ND	14.4
	Total BHC	Bravo/Oscar	Not Measured	1,215
	Total Chlordane	Bravo/Oscar	Not Measured	174
	Heptachlor Epoxide	Bravo/Oscar	Not Measured	174
	Total Endosulfan	Bravo/Oscar	ND	1.09

Table 3.2-2: Sediment Screening Criteria and Background Concentrations for Pearl Harbor Sediment Remedial Investigation (continued)

Parameter		Pier in Pearl Harbor	Background Concentrations (ppm)	Sediment Screening Criteria (mg/kg [ppm], dry weight)
Dioxins	2,3,7,8-TCDD	Bravo/Oscar	Not Measured	0.36

Sources: U.S. Department of the Navy (2010b), Wang et al. (2014a)
Notes: mg = milligram, kg = kilogram, ppm = parts per million, HMW-PAH = high molecular weight-polyaromatic hydrocarbons, PCBs = polychlorinated biphenyls, DDT = dichlorodiphenyltrichloroethane, BHC = benzene hexachloride, TCDD = tetrachlorodibenzo-p-dioxin, < = less than, > = greater than, N/A = not applicable, ND = Not Detected

The Hawaii Undersea Military Munitions Assessment is a comprehensive effort to characterize the potential impacts of chemical and conventional munitions disposed of at sea in a deepwater environment (Edwards et al., 2016b). The program collected data in a location south of Pearl Harbor, Oahu between Barber's Point and Diamond Head from 2007 to 2012 with the goals of defining the bounds of the disposal site, characterizing the state of the munitions found on the seafloor, and assessing the potential impacts that degrading munitions may have on the benthic environment. Researchers mapped the disposal site using high-resolution acoustic imaging, took thousands of digital photos and recorded hundreds of hours of video, and collected physical samples within two meters of munitions to assess sediment contamination. Concentrations of metals detected in sediments at the disposal sites were similar to samples taken from nearby (within 50 m) control sites (Briggs et al., 2016). The chemical warfare agent sulfur mustard and its degradation products were detected as a thin dust-like coating on bottom sediments near chemical munitions. There appeared to be no vertical mixing with adjacent sediments, and the combination of the chemical's low water solubility, the formation of a protective coating by the products of hydrolysis, and near freezing temperatures at the site (greater than 250 m depth), likely resulted in the chemical's persistence as a thin coating (Briggs et al., 2016). There were very few detections of energetic compounds (e.g., explosive materials) at the disposal sites, leading researchers to conclude that the compounds remain contained within the munitions casing or were widely dispersed or degraded before samples were taken.

3.2.2.1.2 Sediment Quality in Nearshore and Offshore Regions of the Southern California Portion of the HSTT Study Area.

The composition and distribution of bottom substrates in the California Current Large Marine Ecosystem are discussed in Section 3.5 (Habitats). In the *National Coastal Condition Report IV* (U.S. Environmental Protection Agency, 2012a), estuarine and coastal ocean areas in the USEPA's West Coast Region, which extents along the entire U.S. West coast, were rated good, fair, or poor for sediment contaminants, toxicity, and total organic carbon. Overall, sediment quality was rated fair. For sediment contaminants, the USEPA rated 96 percent of coastal ocean sediments good, 3 percent fair, and less than 1 percent poor. San Diego Bay exceeded the Effects Range Median threshold for copper, resulting in a fair rating (Figure 3.2-3). Coastal ocean and estuarine waters within the Study Area, including off San Diego, were rated good for contaminants (U.S. Environmental Protection Agency, 2012a). Higher levels of total organic carbon in sediments can be an indicator of higher concentrations of chemical pollutants and poor sediment quality (U.S. Environmental Protection Agency, 2012a).

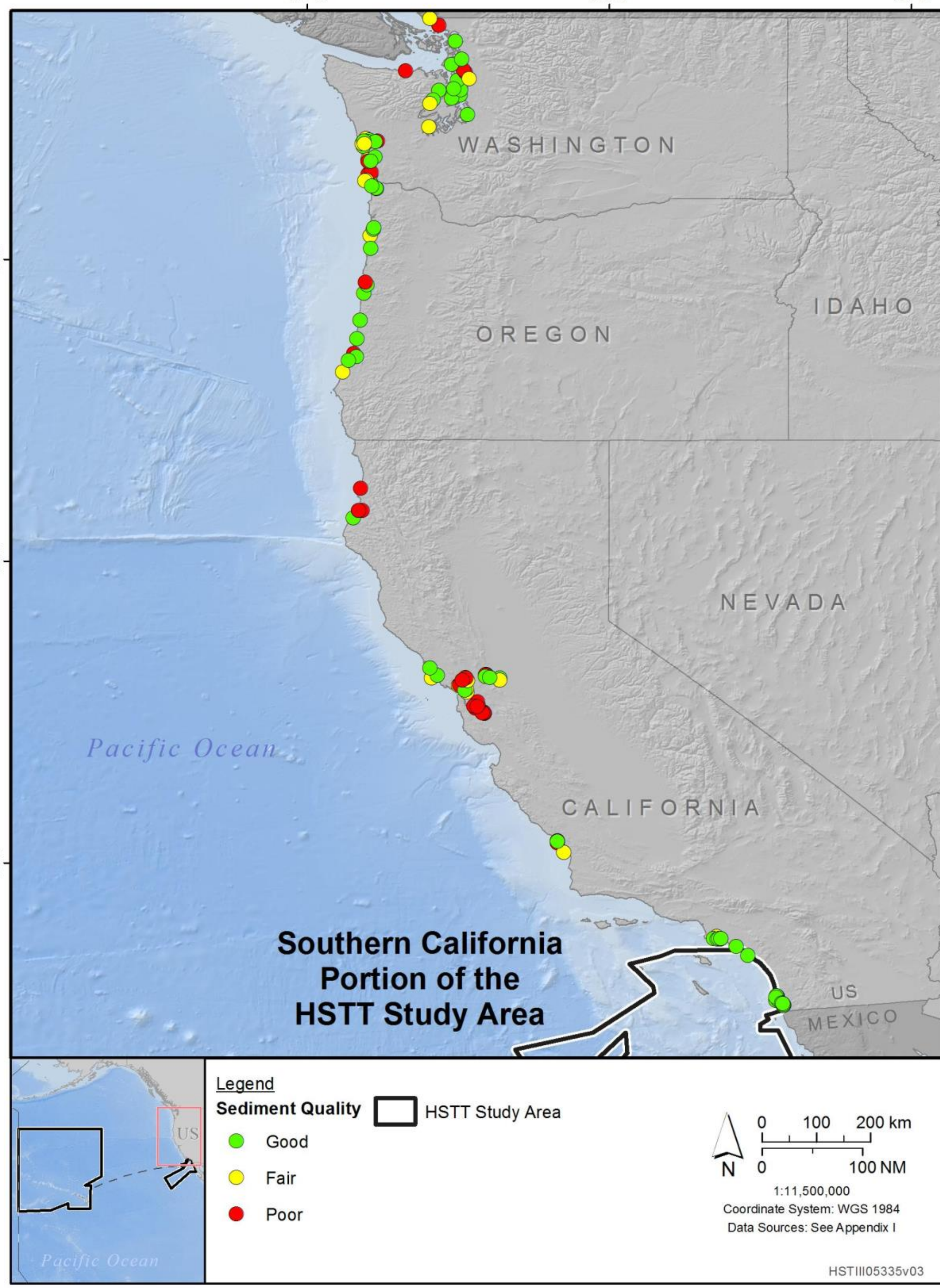

Figure 3.2-3: Sediment Contaminant Rating for the West Coast Region

Note: HSTT = Hawaii-Southern California Training and Testing

Within the West Coast Region, only two sites, both in the Channel Islands, received a poor rating for total organic carbon. Although these sites are located adjacent to the Study Area neither fall within the Study Area boundaries.

In a report on the *Southern California Bight 2013 Regional Monitoring Program*, the Southern California Coastal Water Research Project found that 68 percent of sediments in the Southern California Bight have minimal or low contamination, and less than 1 percent have high contamination, the worst category (Dodder et al., 2016). The Study Area overlaps with approximately the southern half of the Bight, from just north of Santa Catalina Island to the U.S. Mexico border. Higher levels of sediment contamination occurred generally in nearshore embayments rather than in offshore sediments on the continental shelf and slope, and the distribution of contaminants was dependent on the location of the source of the contaminant. For example, concentrations of dichlorodiphenyltrichloroethane (DDT) are higher in sediments off Los Angeles due to long-term discharges from the Los Angeles sanitation district ocean outfall, whereas, copper concentrations are higher in sediments in San Diego Bay, which is home to several large marinas, due to the use of anti-fouling paints on recreational and commercial vessels (Dodder et al., 2016; Neira et al., 2009).

Overall, trends for the entire Bight have been stable since 2003, but the sediment condition for some habitats within the Bight has changed. For example, the spatial extent of sediments with acceptable chemistry in ports, bays, and marinas steadily improved from 40 percent in 1998 to 72 percent in 2013. However, the extent of acceptable sediment chemistry in continental shelf sediments declined from 93 percent in 1998 to 80 percent in 2013, suggesting a possible decline in offshore benthic habitat. The concentrations of some contaminants of emerging concern, such as polybrominated diphenyl ether flame retardants have been reduced, likely due to the implementation of regulations that restrict the production and use of these chemicals beginning in 2010 (Dodder et al., 2016). Between 2008 and 2013, Dodder et al. (2016) report a 10-fold reduction in the average concentration of polybrominated diphenyl ether flame retardants in embayments.

In 2013, for the first time, the Southern California Coastal Water Research Project surveyed sediments in offshore submarine canyons and marine protected areas (Dodder et al., 2016). As suspected, the concentration of sediment contaminants was higher in canyons and marine protected areas that were adjacent to continental shelf areas with higher levels of contaminants, indicating that contaminated sediments on the shelf are being transported into adjacent canyons and marine protected areas. As discussed in Section 3.5 (Habitats) and Chapter 6 (Regulatory Considerations), respectively, there are multiple offshore submarine canyons and marine protected areas located within the Study Area. La Jolla Canyon, Carlsbad Canyon, San Gabriel Canyon, Newport Canyon, and San Pedro Valley all extend into the Study Area.

3.2.2.1.2.1 Sediment Quality off San Clemente Island and the Silver Strand Training Complex

Sediment quality in the waters surrounding San Clemente Island was tested in 2006 (U.S. Department of the Navy, 2006a); concentrations for all contaminants were well below USEPA sediment quality guidelines (Effects Range Median values) (Table 3.2-3). The 10-day solid-phase amphipod bioassay tests of the sediments also indicated high survival and no substantial toxicity. The results indicate that ocean bottom sediment quality is good off San Clemente Island, including areas were training and testing activities occur. An Area of Special Biological Concern has been designated by the California State Water Resources Control Board to include nearshore waters around San Clemente Island out to 1 NM from shore or to the 300 ft. isobath, whichever is greater, along the island's 58-mile coastline. The designation prohibits all waste discharges, both point and non-point, with the exception of a 1,000 ft. radius area at Wilson Cove where the wastewater treatment plant is located (U.S. Department of the Navy, 2013a). A 2011 survey of intertidal habitat and associated biological communities noted no substantial differences between species richness at a discharge site and a reference site, supporting the 2006 data indicating that low contaminant levels good sediment quality (U.S. Department of the Navy, 2013a).

Table 3.2-3: Contaminant Concentrations in Bottom Sediments Offshore of San Clemente Island

Constituent	*Sediment Concentration at SCI Reference Sampling Site (ppm)*	*USEPA Sediment Quality Guidelines (ERM Values) (ppm)*
Arsenic	2.87	70
Cadmium	0.11	9.6
Chromium	8.56	370
Copper	7.48	270
Lead	2.19	218
Mercury	0.275	0.71
Nickel	4.6	51.6
Selenium	0.56	n/a
Silver	0.09	3.7
Zinc	19.2	410
Polychlorinated biphenyls	ND (< 0.005)	180
Phenols	ND (< 0.1)	n/a
Dioxins (TEQ)	0.0–0.028	n/a

Sources: (National Oceanic and Atmospheric Administration, 1999; U.S. Department of the Navy, 2006a)
Notes: ppm = parts per million, ERM = Effects Range Median, ND = not detectable concentration, n/a = not available, TEQ = toxicity equivalency factor, SCI = San Clemente Island, USEPA = United States (U.S.) Environmental Protection Agency, < = less than

Pacific Ocean sediments offshore of Silver Strand have above-average levels of organic loading and concentrations of some metals (aluminum, arsenic, chromium, copper, iron, manganese, and zinc), but these substances are not present at concentrations that pose a risk to public health or the environment. Traces of synthetic organic contaminants (e.g., chemicals released from the burning of coal) are occasionally detected in sediments, but have been well below a threshold of concern (U.S. Army Corps of Engineers, 2002, 2012). Concentrations of contaminants and particulate organic matter are highly variable due to changes in the outflow from the Tijuana River, which can increase substantially following heavy rainfall events (Svejkovsky et al., 2010). Sediment sampling in San Diego Bay near Silver Strand Training Complex-North indicates that—while concentrations of some contaminants are elevated above background levels—no contaminants were present at concentrations which would adversely affect marine organisms (U.S. Department of the Navy, 2013a).

3.2.2.1.2.2 Sediment Quality in San Diego Bay

While multiple sources of pollution contribute to contaminants in the bay, including recreational, commercial, and Navy vessels urban runoff is the largest source of pollutants in the bay, contributing more heavy metals than all other sources combined. Despite reductions in the production and use of polybrominated diphenyl ether flame retardants, some of the highest concentrations of the contaminant in the Southern California Bight were reported in San Diego Bay (Dodder et al., 2016). In the past, sources of sediment contamination other than urban runoff in San Diego Bay have included sewage, industrial wastes, discharges from ships, and accidental spills of contaminants (e.g., oil or fuel). Progress has been made to eliminate or reduce the likelihood of these sources of pollutants entering the bay; however many residual contaminants remain imbedded in bay sediments (Thompson et al., 2009; Wang et al., 2014a; Wang et al., 2000). Current sources of pollutants (other than urban runoff) include resuspension of sediments, industries surrounding and using the bay, Navy installations and activities in the bay, underwater hull cleaning, and vessel anti-fouling paints (Wang et al., 2000; Wang et al., 2006).

Known contaminants found in sediments in San Diego Bay include arsenic, copper, chromium, lead, cadmium, selenium, mercury, tin, manganese, silver, zinc, polycyclic aromatic hydrocarbons, petroleum hydrocarbons, polychlorinated biphenyls, chlordane, dieldrin, and dichlorodiphenyltrichloroethane (DDT) (Dodder et al., 2016; Neira et al., 2009; U.S. Department of the Navy, 2000). Sediment sampling in the 1990s revealed that sediment quality indicators were exceeded at all San Diego Bay sampling stations and the number of exceedances was high at most stations (U.S. Department of the Navy, 2013a). Chlordane, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls were the pollutants most often found at elevated concentrations. Copper, lead, mercury and zinc were often found at elevated levels in Naval Shipyard areas, although the data indicate the probability of metal toxicity was low in those areas (U.S. Department of the Navy, 2013a).

Copper concentrations in marinas in San Diego Bay have frequently exceeded water quality standards (Biggs & D’Anna, 2012). Increasing copper concentrations in sediments at Shelter Island marina, a small, manmade basin with only one opening to the bay, coincided spatially with a higher concentration of boats in the marina (Neira et al., 2009). A second study measured copper concentrations before and after boat slips were occupied at the Pier 32 Marina near the middle of San Diego Bay and adjacent to the Sweetwater National Wildlife Refuge (Biggs & D’Anna, 2012). This study provided further confirmation that elevated concentrations of copper in water and sediments are primarily due to copper leaching from boat paints used on recreational and commercial vessels (Biggs & D’Anna, 2012). A follow-on study in the Shelter Island marina by Neira et al. (2009) showed that the elevated copper levels in sediments had widespread impacts on the benthic faunal community in the marina. While the proposed Navy training and testing activities would not use either marina, the studies indicate that elevated copper concentrations in sediments continues to be a concern and is likely to occur in other locations within the bay.

The San Diego Regional Water Quality Control Board assessed sediment contamination data from 161 sampling stations across San Diego Bay to determine the effects of sediment contamination on benthic macrofauna at-large and previously identified sediment clean-up sites (Thompson et al., 2012). The concentrations of 10 contaminants, 5 metals (Cadmium, copper, lead, mercury and zinc) and 5 organic compounds (total chlordanes, dichlorodiphenyltrichloroethane [DDT], polychlorinated biphenyls, high molecular weight polycyclic aromatic hydrocarbons, and low molecular weight polycyclic aromatic hydrocarbons), were analyzed and ranked on a scale of 1 to 5; sediments receiving a score of 1 were un-impacted and sediments receiving a score of 5 were clearly impacted. The impact score rated the likelihood that the level of contamination would impact benthic macrofauna. Thompson et al. (2012) cites several studies that show sediment toxicity and the probability of associated impacts on biological resources are better represented by indicators that represent mixtures of contaminants rather than concentrations of individual contaminants (see, for example, (Carr et al., 1996; Thompson et al., 2009). One such indicator is the mean Effects Range Median Quotient, which Thompson et al. (2012) uses to evaluate sediment quality in the bay.

With the exception of polycyclic aromatic hydrocarbons, the mean concentrations of contaminants in impacted sediments were between the Effects Range Low and Effects Range Median concentrations (Table 3.2-4). The mean concentrations of chlordanes, copper, dichlorodiphenyltrichloroethane (DDT), and mercury in sediment samples characterized as “un-impacted” exceeded the Effects Range Low value, suggesting some tolerance by biota. Biological impacts correlated more closely with high concentrations of mixtures of contaminants rather than individual contaminants, leading Thompson et al. (2012) to recommend using an indicator such as the mean Effects Range Median quotient as an indicator of sediment quality rather than basing an impacts assessment on the concentrations of individual contaminants in sediments. Based on USEPA guidelines for sediment chemistry using the mean Effects Range Median quotient, the sediment quality in San Diego Bay would be considered fair (i.e., mERMq is between 0.1 and 0.5) (U.S. Environmental Protection Agency, 2016).

Table 3.2-4. Mean Concentration of Contaminants in San Diego Bay for Un-Impacted and Impacted Sediments with Comparison to Effects Ranges

Contaminant	*Units*	*N*	*Mean Concentration of Un-impacted Samples (Score 1 to 2)*	*N*	*Mean Concentration of Impacted Samples (Score 3 to 5)*	*ERL*	*ERM*
Cadmium	µg/g	72	0.209	89	0.342	1.2	9.6
Chlordane	ng/g	57	1.393	71	4.995	0.5	6
Copper	µg /g	72	77.302	89	153.159	34	270
DDTs	ng/g	57	2.362	72	7.302	1.58	46.1
HPAH	ng/g	72	407.126	89	1234.824	1,700	9,600
Lead	µg /g	72	30.528	89	62.71	46.8	218
LPAH	ng/g	72	99.0169	89	202.978	552	3,160
Mercury	µg /g	72	0.314	89	0.489	0.15	0.71
PCBs	ng/g	72	19.72	89	58.68	22.7	180
Zinc	µg /g	72	136.38	89	256.448	150	410
mERMq	ng/g	72	0.166	89	0.332	NA	NA

Source: Thompson et al. (2012)
Notes: DDT = dichlorodiphenyltrichloroethane, HPAH = high molecular weight polycyclic aromatic hydrocarbons, LPAH = Low PAH, PCB = polychlorinated biphenyls, ERM = Effects Range Median, mERMq = mean ERM quotient, ERL = Effects Range Low, µg /g = micrograms per gram, ng/g = nanograms per gram, N = Number of Samples, NA = Not Applicable

Wang et al. (2000; 2014b), use field measurements and a fate and transport model to estimate that docking Navy vessels in San Diego Bay resuspends approximately 26 tons of sediments per day. Wang et al. (2014a) measured sediment resuspension and associated metal contaminants from a tugboat propeller wash at Pier 4-5 in San Diego Bay; measurements included the concentrations of the metals chromium, copper, silver, cadmium, and nickel in the sediment plume. Only copper concentrations exceeded U.S Environmental Protection Agency water quality criteria. However, all metal concentrations, with the exception of cadmium, were increased above ambient levels following resuspension events. Transport of sediments and dissolved or particle-bound metals as a results of propeller wash can potentially result in recontamination of remediated areas as well as increased contaminant concentrations in areas far from piers where docking occurs (Wang et al., 2014a).

While many Navy vessels participating in training and testing activities would use San Diego Bay as the beginning or ending site (or both) of an event, very few training and testing activities would actually occur in the bay (see Chapter 2, Description of Proposed Action and Alternatives; and Appendix A, Navy Activity Descriptions). The majority of training and testing activities would occur more than 3 NM from shore and would not affect sediment quality in San Diego Bay.

3.2.2.1.3 Marine Debris in Nearshore and Offshore Areas off the Hawaiian Islands

A comprehensive review of anthropogenic marine debris, particularly plastics, and their worldwide distribution highlights the growing concern over global environmental impacts and the need for continued scientific research and improved waste disposal management practices (Bergmann et al., 2015). Marine debris in the North Pacific Ocean has been well documented in numerous publications since the early 1970s when Venrick et al. (1973) estimated that there were approximately 4.2 pieces of debris/km^2, most of which were made from plastic, northeast of Hawaii in an area now known as the "North Pacific Garbage Patch" (Bergmann et al., 2015; Venrick et al., 1973). Nearly 40 years later, Titmus and Hyrenback (2011) recorded a density of 459 pieces/km^2 in the same region with over 95 percent of the debris composed of plastic. Analysis of 11 years of data from plankton net tows in the eastern North and South Pacific have allowed researchers to better define the scale of plastic distribution and density (Law et al., 2014). The accumulation of plastic and other debris is largely driven by surface ocean circulation patterns. Large-scale ocean surface currents driven by winds and geostrophic circulation converge in the subtropical North Pacific and result in an accumulation zone for plastic (i.e., the Garbage Patch). The accumulation zone occurs between latitude 25 to 41°N and longitude 130 to 180°W, which is north and primarily east of the Hawaiian Islands (19° 43' N, 155° 05' W). The median concentration of plastics within the accumulation zone was 33,090 pieces/km^2; outside of the zone the median concentration was 0 pieces/km^2. Plastic was collected on some tows outside of the zone. If considering only those tows and not the tows during which no plastic was collected, the median concentration outside of the zone was 1,485 pieces/km^2, approximately 22 times less than within the accumulation zone (Law et al., 2014). Nearly half of all net tows within the accumulation zone collected over 50,000 pieces/km^2, with the area of highest concentrations located between latitude 30 to 35°N and longitude 135 to 140°W, which is farther to the northeast from Hawaii.

Because of their buoyancy, many types of plastic float, and may be transported thousands of miles in the ocean (U.S. Commission on Ocean Policy, 2004). Although plastics are highly resistant to degradation, plastics exposed to ultraviolet radiation from the sun gradually break down into smaller particles through a process called photo oxidation(Law et al., 2010). However, once plastic sinks below the photic zone, degradation rates become very slow, and once plastic reaches the seafloor degradation rates are further reduced. Microbial degradation of plastics in the marine environment does occur, but has a negligible impact on the amount of plastic that persists in the environment, because the process is slow and often occurs in low-oxygen environments on the seafloor (Andrady, 2015). Plastics can take hundreds of years to degrade and some plastics may never fully degrade and would persist in the environment indefinitely (Bergmuller et al., 2007).

As discussed in Section 3.2.2.1.1 (Sediment Quality in Nearshore and Offshore Regions of the Hawaiian Islands), the Hawaii Undersea Military Munitions Assessment documents various types of chemical, explosive, and non-explosive munitions and other military expended materials located on the seafloor in a munitions disposal site south of Pearl Harbor, Oahu (Briggs et al., 2016; Koide et al., 2016). In addition to munitions, materials expended during Navy activities may include but are not limited to, sonobuoy components, guidance wires and fiber optic cables, expendable targets, chaff, and flares (see Appendix F, Military Expended Material and Direct Strike Impact Analyses).

3.2.2.1.4 Marine Debris in Nearshore and Offshore Areas of the Southern California Portion of the HSTT Study Area

The Southern California Bight 2013 Regional Monitoring Program, has for the first time, conducted a comprehensive regional assessment of trash and marine debris in streams and nearshore waters of the Southern California Bight (Moore et al., 2016). While macro-marine debris (debris greater than 5 mm in diameter) found on the seafloor has been quantified in past studies of the Bight, Moore et al. (2016) sampled, for the first time, micro-marine debris (particles 5 mm or less in diameter) imbedded in seafloor sediments. The study analyzed 164 benthic trawl samples and found that one-third of the seafloor in the Southern California Bight contained anthropogenic macro-debris with plastics being the most widespread type of debris. Debris consisted of plastic, cans, glass bottles, metal, lumber, and other debris (e.g., cloth, tape, fiberglass, and caulk). Of the six different habitat areas surveyed, the greatest extent of seafloor containing debris was in Marine Protected Areas (Table 3.2-5). This may be a result of intensive fishing that took place in these areas prior to their designation as marine protected areas, which didn't occur until after 2011. The extent of seafloor macro-debris nearly doubled from 1994 to 2013, and the extent of plastic increased threefold. Plastic macro-debris was found throughout the Bight.

Table 3.2-5: Percent of Macro-Debris Found on Seafloor Habitats in the Southern California Bight

Habitat	*Depth Range (m)*	*Area of Habitat (km^2)*	*Percent of Seafloor Containing Macro-Debris*
Bays	5–30	67	13
Inner Continental Shelf	5–30	975	18
Middle Continental Shelf	31–120	1,528	22
Outer Continental Shelf	121–200	438	35
Upper Continental Slope	201–500	2,857	41
Marine Protected Areas	Variable	137	43

Source: Moore et al. (2016)

The extent and abundance of micro-debris (< 5 mm in diameter) in the Southern California Bight was assessed by collecting 358 sediment samples across 12 different habitats in the Bight. Benthic micro-plastics were found in 38 percent of sediments (Moore et al., 2016). Embayments were the habitat with the greatest relative extent and abundance of micro-plastics, with the vast majority of the seafloor in ports, marinas, and bays containing micro-plastics (Table 3.2-6). Continental shelf habitats had the lowest extent and abundance of benthic micro-plastic. Nylon and high-density polyethylene were the most common polymer types.

Table 3.2-6. Extent and Abundance of Micro-Plastics Found on Seafloor Habitats in the Southern California Bight

Habitat Type	*Percent of Seafloor Containing Micro-Plastics*	*Mean Number of Pieces per Area (Number/0.1 m^2)*
Ports	88	63
Marinas	79	34
Bays	71	8
Estuaries	39	14
Inner Continental Shelf	28	1
Middle Continental Shelf	25	1
Outer Continental Shelf	39	2
Upper Continental Slope	38	2
Marine Protected Area	58	4
Canyon Bottom Sediments	41	4

Source: Moore et al. (2016)

Watters et al. (2010) conducted a visual survey of the seafloor that included a portion of the Navy's Southern California Range Complex as part of a 15-year quantitative assessment of marine debris on the seafloor off the California coast. Watters et al. (2010) found that plastics were the most abundant material and, along with recreational monofilament fishing line, dominated the debris encountered on the seafloor. The visual survey of the seafloor by Watters et al. (2010) encountered only a single object that was potentially "military" in origin (it appeared to be a shell casing). U.S. Navy vessels have a zero-plastic discharge policy and return all plastic waste to appropriate disposal or recycling sites on shore.

In a study of marine debris along the U.S. West Coast, Keller et al. (2010) characterized the composition and abundance of man-made marine debris at 1,347 randomly selected stations during Groundfish Bottom Trawl Surveys that took place in 2007 and 2008. The sample sites included some locations within the Southern California portion of the HSTT Study Area. A subset of the sites sampled included historically used post-World War II dump sites. Recovered items identifying the sites as post-World War II-era dump sites included equipment described as "helmets," "gas masks," "uniforms," and other miscellaneous and diverse items such as "plastic," "file cabinets," and "buckets." Since approximately the 1970s, items such as these are no longer disposed of at sea. The items listed here are not military expended material and would not be expended during training and testing activities in the HSTT Study Area. For this reason, the characterization of "military debris" in Keller et al. (2010) has little if any relevance to the Proposed Action or to present-day standard Navy conduct that (among other procedures) restricts the discharge of plastic at sea.

3.2.2.1.5 Climate Change and Sediment Quality

Aspects of climate change that influence sediments include increasing ocean acidity (pH), increasing sea surface water temperatures, and increasing storm activity. Breitbarth et al. (2010) referred to seawater temperature and pH as "master variables for chemical and biological processes," and noted that effects of changes on trace metal biogeochemistry "may be multifaceted and complex." Under more acidic conditions, metals tend to dissociate from particles to which they are bound in sediments, become more soluble, and potentially more available.

The effects of climate change over the next century will impact water and sediment quality within coastal protected areas within the study area in a variety of ways. Most notably will be the effects of sea level rise and increased tidal surges on natural resources and shore infrastructure, and a diminution of freshwater inputs (U.S. Department of the Navy, 2013a). Marginal bay habitats without protective buffers are most at risk, especially those that require special salinity conditions, intermittent inundation, or light penetration. Changes in water temperature affect mud temperature (Stillman & Paganini, 2015 {Stillman, 2015 #13757) and influence nutrient processing.

As noted in the beginning of this section, tropical storms can have significant impacts on the resuspension and distribution of bottom sediment (Wren & Leonard, 2005). However, no consensus appears to exist on whether climate change will generate more tropical storms or whether those storms will be more intense. If storm frequency and intensity increase, the additional disturbance of sediment may impact water quality in nearshore and coastal areas. A more detailed discussion of this issue is provided in Section 3.2.2.2 (Water Quality).

3.2.2.2 Water Quality

The current state of water quality in the Study Area, from nearshore areas to the open-ocean and deep sea bottom, is discussed below. Additional information on ocean currents in the Study Area is included in Section 3.0.2 (Ecological Characterization of the Study Area). Table 3.2-7 and Table 3.2-8 provide the water quality criteria and an associated index for the U.S. West Coast and the Hawaiian Islands, respectively.

3.2.2.2.1 Water Quality in the Nearshore and Offshore Waters of the Hawaiian Islands

The offshore waters of the Hawaii Range Complex and beyond to the boundaries of the HSTT Study Area are expansive. The area includes nearshore waters and shallow intra-island channels as well as deep offshore waters beyond the U.S. Exclusion Economic Zone (i.e., the "high seas"). Small-scale oceanographic processes like coastal upwelling and large-scale features, like the North Equatorial Current, result in the formation of leeward eddies, vertical mixing, and horizontal transport of water from nearshore to offshore areas. Persistent easterly winds have a strong influence on circulation in the upper water column.

Population growth is the primary cause of impacts on the coastal water quality of the Hawaiian Islands. The coastal waters of the Hawaiian Islands are affected by different kinds of marine debris, garbage, and solid wastes that deposit toxic chemicals and nutrients in the ocean. In addition to large quantities of marine debris, polychlorinated biphenyls have been deposited in the marine environment because of urbanization (Center for Ocean Solutions, 2009). Urban land use typically results in water quality contaminants such as nitrogen, phosphorous, suspended solids, sediments, pesticides, and herbicides, as well as fecal contamination. Agricultural runoff contains the same water quality contaminants as urban runoff, but has higher concentrations of pesticides, herbicides, and sediments.

A survey for the *National Coastal Condition Report III* of 50 stations across the main islands and 29 stations along the southern shore of Oahu, mostly near heavily urbanized areas, resulted in a water quality index of "good" (U.S. Environmental Protection Agency, 2008a) (Figure 3.2-4). This rating was based on five indicators: concentrations of dissolved inorganic nitrogen, dissolved inorganic phosphorus, chlorophyll-*a*, dissolved oxygen, and water clarity. Most of the coastal area surveyed (78 percent) was rated "good," while 18 percent of the surveyed area was "fair" and 4 percent was considered "poor." The finding of 22 percent considered either fair or poor is preliminary because some stations did not measure all five component indicators (U.S. Environmental Protection Agency, 2008a).

The state of Hawaii has approximately 575 marine water bodies established statewide. In 2014, the Hawaii State Department of Health reported on the condition of 160 (28 percent) of these water bodies based on new, readily available water quality data collected from 2011 through 2013 (Hawaii Department of Health, 2014). Of the 160 marine water bodies assessed statewide, 136 (85 percent) did not attain state numeric water quality criteria for at least one or more conventional pollutants. The criteria pollutants assessed in the report are turbidity, nutrients, chlorophyll-*a*, and bacteria. Turbidity criteria were exceeded most often with 86 percent of assessed water bodies in non-attainment. Nutrient criteria, the second most frequently exceeded criteria, were above threshold in 46 percent of assessments; the converse being that 54 percent of water bodies were in attainment for nutrients—a positive sign. In addition, 90 percent of assessments were in attainment for bacteria, which is used as a recreational health criteria.

The impact of each of the four measured pollutants varied within the islands. On Kauai, 100 percent of assessed water bodies exceeded turbidity criteria (Hawaii Department of Health, 2014). Turbidity was also in non-attainment in assessed marine water bodies on Maui (92 percent), Hawaii (80 percent), and Oahu (78 percent). Over 70 percent of assessed water bodies on Maui and the island of Hawaii were in non-attainment for nutrients as well. However, the majority of assessed marine water bodies were in attainment for nutrients on Kauai (56 percent), Oahu (95 percent), and Lanai (88 percent), and the majority of water bodies assess on Kauai, Oahu, and the Island of Hawaii were in attainment for chlorophyll-*a* (100, 69, 53 percent, respectively). Another positive sign of water quality improvements in Hawaii is the removal or "delisting" of four marine water bodies on Oahu; Ewa Beach, Ocean Pointe C, Pokai Bay and Sandy Beach from the Clean Water Act Section 303(d) list of impaired waters (Hawaii Department of Health, 2014).

Pearl Harbor is on Hawaii's Clean Water Act Section 303(d) list of impaired waters. The Pearl Harbor Water Quality Limited Segment includes the entire harbor and the mouths of perennial streams discharging into the harbor. Beneficial uses of Pearl Harbor include bait fish and shellfish propagation in West and East Lochs, shipping navigation and industrial water in East Loch, and water fowl habitat in Middle and West Lochs (Hawaii State Department of Health, 2000).

Contaminants are introduced into Pearl Harbor via point source and non-point source discharges. Surface runoff from urban, industrial, and agricultural activities carries variable levels of herbicides, pesticides, and other contaminants, in addition to natural loads of sediment, dissolved metals, and other soluble constituents (Agency for Toxic Substances and Disease Registry, 2005). Water quality criteria that are frequently violated in Pearl Harbor include maximum nitrogen, phosphorous, fecal coliform, and chlorophyll-*a* concentrations, and turbidity and temperature limits (Hawaii State Department of Health, 2000). The Hawaii State Department of Health assessment of water quality in 160 marine water bodies included an evaluation of water quality in Pearl Harbor (Hawaii Department of Health, 2014). Waters in Pearl Harbor were in non-attainment for total phosphorous, total nitrogen, and chlorophyll-*a*, but were in attainment for turbidity. The presence of contaminants including polychlorinated biphenyls (PCBs), pesticides, and lead continue to restrict the consumption of fish and shellfish caught in Pearl Harbor.

Table 3.2-7: Water Quality Criteria and Index, United States West Coast

Criterion	***Site Criteria***			***Regional Criteria***		
	Good	***Fair***	***Poor***	***Good***	***Fair***	***Poor***
Dissolved Inorganic Nitrogen	< 0.5 mg/L	0.5–1.0 mg/L	> 1.0 mg/L	Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.	10–25% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 25% of the coastal area is in poor condition.
Dissolved Inorganic Phosphorus	< 0.01 mg/L	0.01–0.1 mg/L	> 0.1 mg/L			
Water Clarity	Sites with naturally high turbidity: > 10% light at 1 meter Sites with normal turbidity: > 20% light at 1 meter Sites that support submerged aquatic vegetation: > 40% light at 1 meter	Sites with naturally high turbidity: 5–10% light at 1 meter Sites with normal turbidity: 10–20% light at 1 meter Sites that support submerged aquatic vegetation: 20–40% light at 1 meter	Sites with naturally high turbidity: < 5% light at 1 meter Sites with normal turbidity: < 10% light at 1 meter Sites that support submerged aquatic vegetation: < 20% light at 1 meter			
Dissolved Oxygen	> 5.0 mg/L	2.0-5.0 mg/L	< 2.0 mg/L	Less than 5% of the coastal area is in poor condition and more than 50% of the coastal area is in good condition.	5–15% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 15% of the coastal area is in poor condition.
Chlorophyll-*a*	< 5 µg/L	5–20 µg/L	> 20 µg/L	Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.	10–20% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 20% of the coastal area is in poor condition.
Water Quality Index	A maximum of one indicator is rated fair, and no indicators are rated poor.	One of the indicators is rated poor, or two or more indicators are rated fair.	Two or more of the five indicators are rated poor.			

Source: U.S. Environmental Protection Agency (2009)
Notes: < = less than, > = greater than, mg/L = milligram per liter, µg/L = microgram per liter

Table 3.2-8: Water Quality Criteria and Index, Hawaiian Islands

<table>
<tr><th rowspan="2">Criterion</th><th colspan="3">Site Criteria</th><th colspan="3">Regional Criteria</th></tr>
<tr><th>Good</th><th>Fair</th><th>Poor</th><th>Good</th><th>Fair</th><th>Poor</th></tr>
<tr><td>Dissolved Inorganic Nitrogen</td><td>< 0.05 mg/L</td><td>0.05–0.1 mg/L</td><td>> 0.1 mg/L</td><td rowspan="3">Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.</td><td rowspan="3">10–25% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.</td><td rowspan="3">More than 25% of the coastal area is in poor condition.</td></tr>
<tr><td>Dissolved Inorganic Phosphorus</td><td>< 0.005 mg/L</td><td>0.005–0.01 mg/L</td><td>> 0.01 mg/L</td></tr>
<tr><td>Water Clarity</td><td>Sites with naturally high turbidity:
> 10% light at 1 meter
Sites with normal turbidity:
> 20% light at 1 meter
Sites that support submerged aquatic vegetation:
> 40% light at 1 meter</td><td>Sites with naturally high turbidity:
5–10% light at 1 meter
Sites with normal turbidity:
10–20% light at 1 meter
Sites that support submerged aquatic vegetation:
20–40% light at 1 meter</td><td>Sites with naturally high turbidity:
< 5% light at 1 meter
Sites with normal turbidity:
< 10% light at 1 meter
Sites that support submerged aquatic vegetation:
< 20% light at 1 meter</td></tr>
<tr><td>Dissolved Oxygen</td><td>> 5.0 mg/L</td><td>2.0–5.0 mg/L</td><td>< 2.0 mg/L</td><td>Less than 5% of the coastal area is in poor condition and more than 50% of the coastal area is in good condition.</td><td>5%-15% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.</td><td>More than 15% of the coastal area is in poor condition.</td></tr>
<tr><td>Chlorophyll-a</td><td>< 0.5 µg/L</td><td>0.5–1.0 µg/L</td><td>> 1.0 µg/L</td><td rowspan="2">Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.</td><td rowspan="2">10%-20% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.</td><td rowspan="2">More than 20% of the coastal area is in poor condition.</td></tr>
<tr><td>Water Quality Index</td><td>A maximum of one indicator is rated fair, and no indicators are rated poor.</td><td>One of the indicators is rated poor, or two or more indicators are rated fair.</td><td>Two or more of the five indicators are rated poor.</td></tr>
</table>

Source: U.S. Environmental Protection Agency (2009)
Notes: < = less than, > = greater than, mg/L= milligram per liter, µg/L = microgram per liter

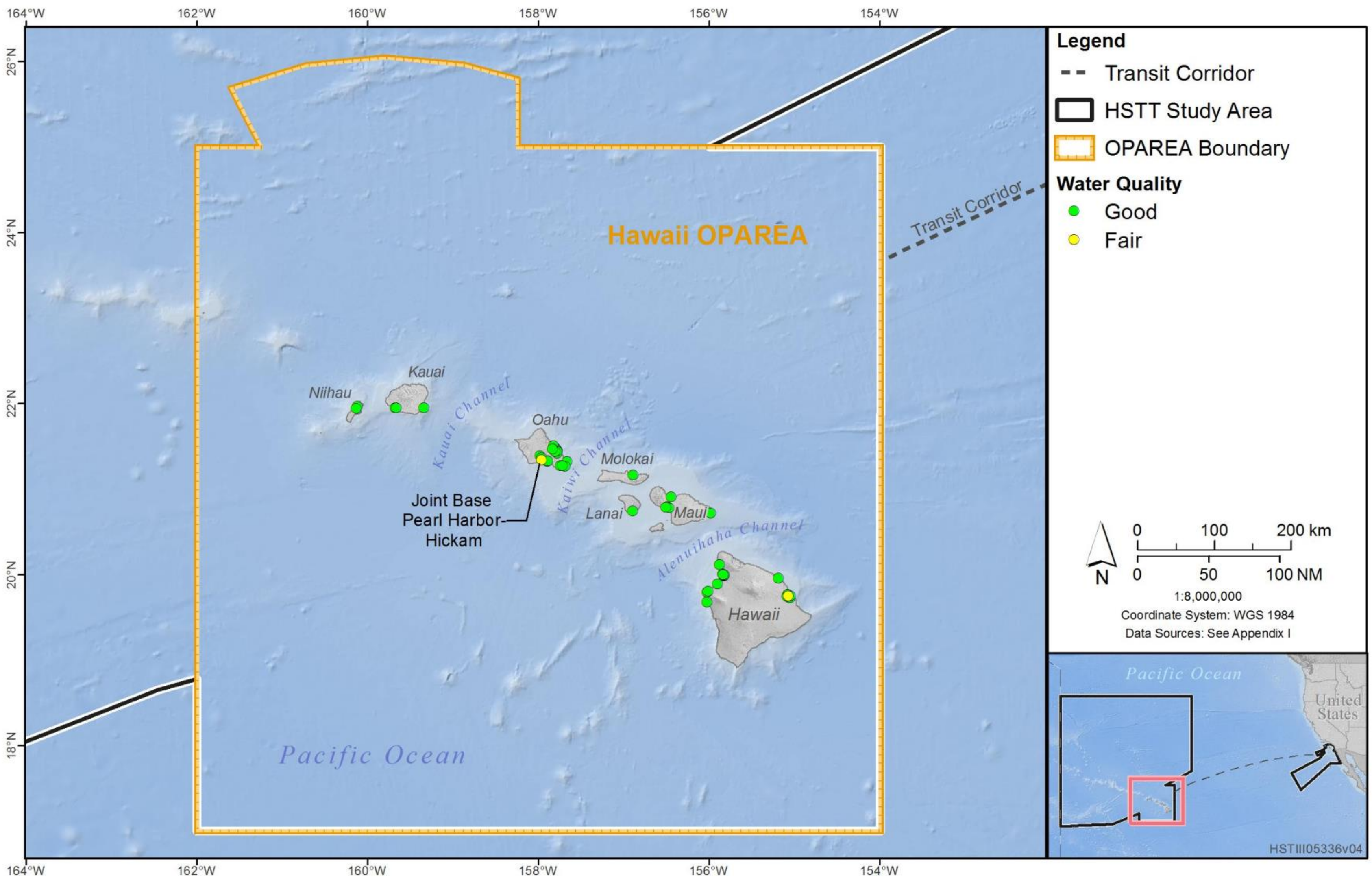

Figure 3.2-4: Water Quality Index for the Hawaiian Islands

Notes: HSTT = Hawaii Southern California Training and Testing, OPAREA = Operating Area

3.2.2.2.2 Water Quality in the Nearshore and Offshore Waters in the Southern California Portion of the HSTT Study Area

The offshore waters of the Southern California portion of the HSTT Study Area are vast. Their expanse includes nearshore waters and coastal bays as well as offshore waters beyond the U.S. Exclusive Economic Zone (the "high seas"). Small- and large-scale oceanographic processes, including coastal upwelling and advection by offshore currents, result in broad vertical mixing throughout the upper water column and horizontal transport of water from nearshore to offshore areas, which maintain generally high water quality levels that meet or exceed criteria set forth by the *California Ocean Plan* (State of California, 2009) and by the *National Ambient Water Quality Criteria* (U.S. Environmental Protection Agency, 2009). The water quality index for the coastal waters of the West Coast region, extending from Southern California to Canada, is rated good, with 19 percent of the coast rated fair and only 2 percent rated poor (Figure 3.2-5) (U.S. Environmental Protection Agency, 2012a).

The water quality index for the West Coast region is based on the same criteria identified for the Hawaiian Islands in Section 3.2.2.2.1 (Water Quality in the Nearshore and Offshore Waters of the Hawaiian Islands).

Water quality in the Southern California portion of the HSTT Study Area is strongly affected by human activities in heavily developed Southern California. Urban runoff is the largest source of contaminants in San Diego Bay and along the rest of the Southern California coast, and can transport bacteria, inorganic nutrients, various organic compounds, metals, and debris into downstream or adjacent water bodies.

Nonpoint source runoff is substantial in Southern California, because most rivers are highly modified stormwater conveyance systems that are not connected to sewage treatment systems. When storm events occur, runoff plumes can become large oceanographic features that extend for many miles (Center for Ocean Solutions, 2009). Along the Southern California coast, land-based chemical pollution, in particular polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT), affect water quality.

Most of the marine water pollution in the Southern California portion of the HSTT Study Area results from municipal discharges. The oil and gas industry, however, is a source of water pollution in the northern part of the Southern California Bight. Several active oil platforms are located near the northern boundary of the Southern California Range Complex. As offshore oil and gas activities continue in Southern California, potential pollutants may be introduced into the marine environment through oil leaks, accidental spills, discharges of formation water, drill mud, sediment, debris, and sludge, all of which degrade water quality.

Commercial, recreational, and institutional vessels also discharge water pollutants in the Southern California portion of the HSTT Study Area. Shipboard waste-handling procedures governing the discharge of nonhazardous waste streams have been established for commercial and Navy vessels. These categories of wastes include (1) liquids: "black water" (sewage); "grey water" (water from deck drains, showers, dishwashers, laundries, etc.); and oily wastes (oil-water mixtures) and (2) solids (garbage).

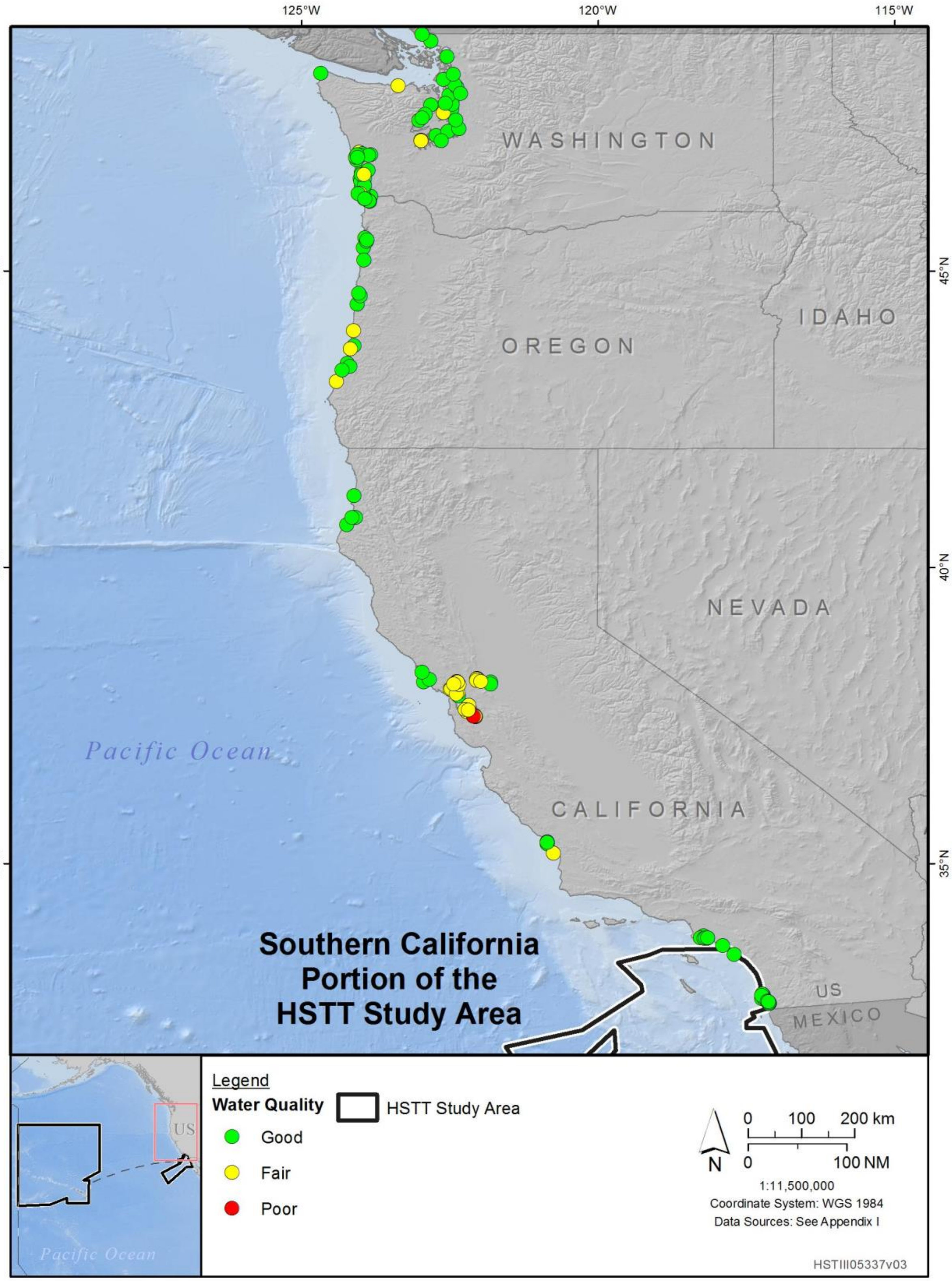

Figure 3.2-5: Water Quality Index for the West Coast Region

Notes: HSTT = Hawaii Southern California Training and Testing

Water quality in the nearshore waters of San Clemente Island, which are affected by baseline at-sea and ashore training and testing activities, has been tested (U.S. Department of the Navy, 2006a), and was reassessed for the 2010 San Clemente Island Range Condition Assessment (U.S. Department of the Navy, 2010c). Surface water and nearshore sediments just beyond the surf zone were sampled for metals, cyanide, chlorine, ammonia, phenols, pesticides, gross alpha/beta, perchlorate, and dioxin. Both acute and chronic toxicity tests were conducted with test organisms that included algae (kelp), an invertebrate (mussel), and a fish (topsmelt larvae). Two sample locations were in close proximity to the island's land-based shore bombardment area located on the southern end of the island. Samples from these two location would be the most likely to show signs of munitions constituents entering the marine environment. Results indicated that most chemicals were not detected in receiving water and sediment samples, and in the cases where chemicals were detected and criteria were available, results fell well below all chemistry-related numerical objectives. The assessment concluded that only traces of the explosive compound HMX were detected in surface water—no other munitions constituents were detected, and HMX was detected only in a duplicate sample at five orders of magnitude below the threshold requiring that some level of action be taken. Therefore, although it appears that some munitions constituents may be migrating into the Pacific Ocean, they are doing so at concentrations well below levels of concern and well below concentrations that would be detectable in ocean water. Furthermore, no statistically significant toxicity was observed in topsmelt, giant kelp, or bivalve bioassays. These data suggest that Navy discharges from San Clemente Island do not compromise protection of ocean waters for beneficial uses around San Clemente Island.

Based on *California Ocean Plan* objectives for protection of aquatic life, concentrations of potential water pollutants are low, and have no substantial effects on marine water quality in a portion of the Southern California Range Complex where training and testing activities are most concentrated (U.S. Department of the Navy, 2013d).

Major contaminants found in San Diego Bay include chlorinated hydrocarbons, polychlorinated biphenyls, toxic components of petroleum hydrocarbons, polycyclic aromatic hydrocarbons, heavy metals, and organotins such as tributyltin (U.S. Department of the Navy, 2013a). The sources of these compounds include effluents from non-point-source storm drain runoff (municipal and industrial); contaminants from vessel maintenance; antifouling paints (military, commercial, and private vessels); marina discharges; and residues of prior industrial discharges. These contaminants have generally been incorporated into bottom sediments in the bay, and are periodically re-suspended in the water column when bottom sediments are disturbed by natural or human activities.

Water quality in north and central San Diego Bay is affected primarily by tidal flushing and currents. Water quality also is influenced locally by freshwater inflows. The watershed that contributes to San Diego Bay has a number of Total Maximum Daily Loads established for Chollas Creek and Shelter Island for criteria such as diazinon, dissolved metals, and indicator bacteria (U.S. Department of the Navy, 2013a). Gross water quality characteristics (e.g., salinity, temperature, and dissolved oxygen) form a gradient within San Diego Bay. Waters in northern San Diego Bay are similar to ocean conditions; waters in southern San Diego Bay are strongly affected by shallow depths, fresh water inflows, and solar insolation; waters in central San Diego Bay are intermediate in character.

3.2.2.2.3 Marine Debris and Water Quality

The National Marine Debris Monitoring Program developed three categories of marine debris for its study of the extent of man-made materials in the oceans: land-based, ocean-based, and general (i.e., origin unspecified) (Sheavly, 2007). Land-based debris may blow in on the wind, be washed in with storm water, arise from recreational use of coastal areas, and be generated by extreme weather such as tsunamis. Ocean-based sources of marine debris include commercial shipping and fishing, private boating, offshore mining and extraction, and legal and illegal dumping at sea. Ocean current patterns, weather and tides, and proximity to urban centers, industrial and recreational areas, shipping lanes, and fishing grounds influence the types and amount of debris found (U.S. Environmental Protection Agency, 2010). These materials are concentrated at the near-surface and in the water column.

According to the U.S. Environmental Protection Agency (2010), land-based sources account for about half of marine debris, and ocean/waterway-based sources contribute another 18 percent. Bergmuller et al. (2007) confirm that the majority of marine debris originates from land. Land-based debris included items like syringes, condoms, metal beverage cans, motor oil containers, balloons, six-pack rings, straws, tampon applicators, and cotton swabs. Ocean-based debris included gloves, plastic sheets, light bulbs and tubes, oil and gas containers, pipe-thread protectors, nets, traps and pots, fishing line, light sticks, rope, salt bags, fish baskets, cruise line logo items, and floats and buoys. Plastics, generally referring to petroleum-based, manmade materials, make up the vast majority of marine debris (Bergmuller et al., 2007; Law & Thompson, 2014).

Within the HSTT Study Area, Currie et al. (2017) conducted surveys for marine mammals and floating marine debris in the waters around the island of Lanai and waters between Lanai and the islands of Maui and Kahoolawe from April 2013 to April 2016. The survey encountered, collected, and categorized 1,027 pieces of marine debris. Items categorized as “plastic” were the predominant type of debris encountered and accounted for 86 percent of total debris. Plastics consisted mainly of plastic bottles, tubs, baskets, foamed polystyrene disposable plates, cups, fragments, plastic bags, and other soft plastic films. A smaller portion of the plastic (13 percent; 11 percent of the total amount of material) were fishing-related and included items such as buoys, netting, rope, and fishing lines. Milled lumber and rubber accounted for 10 percent of total debris, and the remaining 4 percent consisted of metal, glass, and clothing/fabric.

Microscopic plastic fragments enter the marine environment from use as scrubbers in hand cleaning and other cosmetic products, abrasive beads for cleaning ships, and deterioration of macroscopic plastics (Teuten et al., 2007). Microplastic beads commonly used in cosmetic products such as facial scrubs and other exfoliants are not broken down in wastewater treatment facilities and are largely not filtered out of the waste stream before they are flushed into the marine environment (Chang, 2015; Napper et al., 2015). These microbeads are found worldwide in marine sediments, persist in the marine environment, and accumulate up the food chain (Cole & Galloway, 2015).

Plastics may serve as vehicles for transport of various pollutants, whether by binding them from seawater or from the constituents of the plastics themselves. Mato et al. (2001) noted that polypropylene resin pellets (precursors to certain manufactured plastics) collected from sites in Japan contained polychlorinated biphenyls, dichlorodiphenyldichloroethylene (a breakdown product of DDT), and the persistent organic pollutant nonylphenol (a precursor to certain detergents). Polychlorinated biphenyls and dichlorodiphenyldichloroethylene were adsorbed from seawater and accumulated on the surface of plastics. The original source of nonylphenol was less clear; it may have originated from the pellets themselves or may have been adsorbed from the seawater. Microbeads have also been shown to adsorb hydrophobic chemical contaminants, such as dichlorodiphenyltrichloroethane (DDT), from seawater, allowing for the accumulation and transport of these often toxic chemicals to widely dispersed areas of the oceans. While the impacts on the marine ecosystem are largely unknown, some examples illustrating potential widespread impacts have been discussed. For example, it has been suggested that white and blue microplastic beads, common in many exfoliants, resemble plankton and may be mistakenly ingested by plankton-feeding fishes, which rely on visual cues to find prey (Napper et al., 2015; Wright et al., 2013). The long-term effects on the environment from the proliferation of microbeads and other micro plastics are still being researched. Since there is no way of effectively removing micro plastics from the marine environment, and given that plastics are highly resistant to degradation, it is likely that the quantity of micro plastics in the marine environment will only continue to increase, and therefore the likelihood of environmental impacts can only increase (Napper et al., 2015). The only way to reduce long-term impacts is to reduce or eliminate the use of micro plastics, a course of action that is gaining recognition (Chang, 2015).

Because of their buoyancy, many types of plastic items float and may travel thousands of miles in the ocean (U.S. Commission on Ocean Policy, 2004). Exceptions include heavy nets and ropes. Although plastics are resistant to degradation, they do gradually break down into smaller particles due to sunlight and mechanical wear (Law et al., 2010). A study by Teuten et al. (2007) indicated that the water-borne phenanthrene (a type of polycyclic aromatic hydrocarbon) adhered preferentially to small pieces of plastic ingested by a bottom-dwelling marine lugworm and incorporated into its tissue. Marine microbes and fungi are known to degrade biologically produced polyesters, such as polyhydroxyalkanoates, a bacterial carbon and energy source (Doi et al., 1992). Marine microbes also degrade other synthetic polymers, although at slower rates (Shah et al., 2008).

Annex V of the International Convention for the Prevention of Pollution from Ships prohibits the discharge of plastic waste from vessels at sea, and the U.S. Act to Prevent Pollution from Ships brought U.S. public vessels in alignment with the international convention. The National Defense Authorization Act of 1996 specifically directed the Navy to install plastic waste processors aboard the surface fleet. The U.S. Navy's plastics waste processors compress and melt shipboard-generated plastic waste into dense, sanitary disks of compressed plastics that can be stored over long at-sea deployments. The plastic wastes items include lightly contaminated food containers as well as clean plastics and other materials that may be combined with, or contain, plastic components that cannot be processed in the normal solid waste stream. The plastic waste disks are offloaded for proper disposal once a ship comes into port. The plastic compression technology enables Navy ships to operate at sea over long time periods without discharging plastics into the oceans.

3.2.2.2.4 Climate Change and Water Quality

According to the U.S. Global Change Research Program, the rise in ocean temperature over the last century will continue into the reasonably foreseeable future, with continued and perhaps increasing impacts on ocean circulation, marine chemistry, and marine ecosystems. Because the ocean currently absorbs about a quarter of human-produced carbon dioxide emissions, increasing carbon dioxide absorption will increase acidification of ocean waters. This in turn will alter the distribution, abundance, and productivity of many marine species (Melillo et al., 2014).

Key findings of the 2014 National Climate Assessment that may pertain to waters surrounding the Hawaiian Islands include:

- Warmer oceans are leading to increased coral bleaching events and disease outbreaks in coral reefs, as well as changed distribution patterns of tuna fisheries. Ocean acidification will reduce coral growth and health. Warming and acidification, combined with existing stresses, will strongly affect coral reef fish communities.

- Saltwater intrusion associated with sea level rise will reduce the quantity and quality of freshwater in coastal aquifers, especially on low islands.

- Rising sea levels, coupled with high water levels caused by storms, will incrementally increase coastal flooding and erosion, damaging coastal ecosystems, infrastructure, and agriculture, and indirectly affecting tourism.

Key findings of the 2014 National Climate Assessment that may pertain to waters off California include:

- With the decreases in snowpack and streamflow expected to continually decline, freshwater inputs into California's coastal estuaries will decrease, with subsequent losses of ecosystem services that estuaries provide (e.g., nutrient cycling, filtration).

- Sea level rise is projected to increase, resulting in major damage as wind-driven waves ride upon higher seas and reach farther inland.

The Paris Agreement builds upon the Convention and – for the first time – brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so. As such, it charts a new course in the global climate effort.

At the 2015 Paris Climate Conference, 195 parties to the United Nations Framework Convention on Climate Change adopted the first-ever universal, global climate agreement, referred to as the Paris Agreement in which all countries voluntarily set and committed to individual carbon reduction goals. The Agreement marks the latest step in the evolution of the United Nations climate change initiative and builds on the work undertaken under the Convention over the past several decades.

The Paris Agreement seeks to accelerate and intensify the actions and investment needed for sustaining low carbon emissions into the future. Its central aim is to strengthen the global response to the threat of climate change and greenhouse gas emissions by limiting a global temperature rise over this century to no more than 2 degrees Celsius above pre-industrial levels. The Paris Agreement also includes a commitment to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.

The United States signed the Paris Agreement on April 22, 2016, and on September 3, 2016, the United States accepted ratification of the Agreement. However, on June 1, 2017, the President announced that the United States would withdraw from the Paris Agreement. The official withdrawal requires a formal process, which will take nearly four years to complete. According to the rules of the Paris Agreement, a nation wishing to withdraw must first submit a document to the United Nations specifying its intent to withdraw. The submission of the document is permitted only after three years have passed since the agreement entered into force, in this case November 4, 2016. The earliest the United States can submit its written notice is November 4, 2019, and the earliest the United States could complete the withdrawal process is November 4, 2020.

3.2.3 Environmental Consequences

This section evaluates how and to what degree the training and testing activities described in Chapter 2 (Description of Proposed Action and Alternatives) may impact sediments and water quality in the Study Area. Tables 2.6-1 through 2.6-5 present proposed training and testing activity locations for each alternative, including number of events conducted annually and over a 5-year period for Alternatives 1 and 2. Appendix A (Navy Activity Descriptions) includes descriptions of all training and testing activities, including the type of munitions and other expended materials used during the activity. Each water quality stressor is introduced, analyzed by alternative, and analyzed for training activities and testing activities. Potential impacts could be from

- releasing materials into the water that subsequently disperse, react with seawater, or may dissolve over time;
- depositing materials on the ocean bottom and any subsequent interactions with sediments or the accumulation of such materials over time;
- depositing materials or substances on the ocean bottom and any subsequent interaction with the water column; and
- depositing materials on the ocean bottom and any subsequent disturbance of those sediments or their resuspension in the water column.

These potential impacts may result from four stressors: (1) explosives and explosives byproducts, (2) metals, (3) chemicals other than explosives, and (4) other materials. The term “stressor” is used because materials in these four categories may directly impact sediments and water quality by altering their physical and chemical characteristics.

The area of analysis for sediments and water quality includes estuaries, nearshore areas, and the open ocean (including the seafloor) in the Study Area. The environmental fate of explosives, explosives byproduct, metals, and other materials depends on environmental factors, geochemical conditions, and various mechanisms that transport the constituents in the environment. Some natural transport mechanisms, such as advection by currents, dispersion, dissolution (dissolving), precipitation by chemical reaction, and adsorption (the adhesion of a chemical constituent onto the surface of a particle in the environment [e.g., clay]) reduce concentrations in water and redistribute constituents between the water and sediments. Other processes, such as biodegradation, may change or destroy the explosive compounds but would not affect metals. For this analysis, potential impacts on sediments and water quality from military expended materials that are deposited in sediments at any given distance from shore are assumed to be similar.

3.2.3.1 Explosives and Explosives Byproducts

Explosives may be introduced into the seawater and sediments by the Proposed Action. The explosive fillers contained within the munitions used during training and testing activities and their degradation products can enter the environment through high-order detonations (i.e., the munition functions as intended and the vast majority of explosives are consumed), low-order detonations (i.e., the munition partially functions with only a portion of the explosives consumed), or unexploded munitions (i.e., the munition fails to detonate and explosives remain in the casing). In the case of a successful detonation, only a small or residual amount of explosives may enter the marine environment (U.S. Environmental Protection Agency, 2012b). A low-order detonation would result in some residual explosives and some unconsumed explosives remaining in the munitions casing entering the water. In the case of unexploded munitions, the explosives contained in the munition would not be consumed and would remain encased within the munition as it enters the marine environment. The munitions casing may corrode or rupture over time and release explosives into the sediments and water column.

The behavior of explosives and explosives byproducts in marine environments and the extent to which those constituents of explosives have adverse impacts are influenced by a number of processes, including the ease with which the explosive dissolves in a liquid such as water (solubility), the degree to which explosives are attracted to other materials in the water (e.g., clay-sized particles and organic matter, sorption), and the tendency of the explosives to evaporate (volatilization). These characteristics, in turn, influence the extent to which the material is subject to biotic (biological) and abiotic (physical and chemical) transformation and degradation (Pennington & Brannon, 2002). The solubility of various explosives is provided in Table 3.2-9. In the table, higher values indicate greater solubility. For example, high melting explosive is virtually insoluble in water. Table salt, which dissolves easily in water, is included in the table for comparison.

Table 3.2-9: Water Solubility of Common Explosives and Explosive Degradation Products

Compound	***Water Solubility[1] (mg/L at 20 ˚C)***
Table salt (sodium chloride)[2]	357,000
Ammonium perchlorate (O)	249,000
Picric acid (E)	12,820
Nitrobenzene (D)	1,900
Dinitrobenzene (E)	500
Trinitrobenzene (E)	335
Dinitrotoluene (D)	160
TNT (E)	130
Tetryl (E)	51
Pentaerythritoltetranitrate (E)	43
Royal Demolition Explosive (E)	38
High Melting Explosive (E)	7

Source: (U.S. Department of the Navy, 2008b)
[1] Units are milligrams per liter at 20 degrees Celsius
[2]Table salt is not an explosive degradation product
Notes: D = explosive degradation product, E = explosive, O = oxidizer additive, TNT = trinitrotoluene

According to Walker et al. (2006), trinitrotoluene (TNT), royal demolition explosive, and high melting explosive experience rapid biological and photochemical degradation in marine systems. The authors noted that productivity in marine and estuarine systems is largely controlled by the limited availability of nitrogen. Because nitrogen is a key component of explosives, they are attractive as substrates for marine bacteria that metabolize other naturally occurring organic matter, such as polycyclic aromatic hydrocarbons. Juhasz and Naidu (2007) also noted that microbes use explosives as sources of carbon and energy.

Carr and Nipper (2003) indicated that conversion of trinitrotoluene (TNT) to carbon dioxide, methane, and nitrates in coastal sediments (a process referred to as “mineralization”) occurred at rates that were typical for naturally occurring compounds such as phenanthrene, fluoranthene, toluene, and naphthalene. They noted that transformation of 2, 6-dinitrotoluene and picric acid by organisms in sediments is dependent on temperature and type of sediment (e.g., finer-grained). Pavlostathis and Jackson (2002) reported that the marine microalgae *Anabaena* spp. was highly efficient at the removal and metabolism of trinitrotoluene (TNT) in a continuous flow experiment. Nipper et al. (2002) noted that irreversible binding to sediments and biodegradation of 2, 6-dinitrotoluene, tetryl, and picric acid occurred in fine-grained sediments high in organic carbon resulting in lower concentrations of the contaminants. Cruz-Uribe et al. (2007) noted that three species of marine macroalgae metabolize trinitrotoluene (TNT) to 2-amino-4,6-dinitrotoluene and 4-amino-2, 6-dinitrotoluene, and speculate that "the ability of marine macroalgae to metabolize trinitrotoluene (TNT) is widespread, if not generic." The studies cited above indicate that trinitrotoluene (TNT) and its constituent products can be removed from the environment by naturally occurring biological processes in sediments, reducing sediment toxicity from these chemical contaminants.

Singh et al. (2009) indicated that biodegradation of royal demolition explosive and high melting explosive occurs with oxygen (aerobic) and without oxygen (anoxic or anaerobic), but that they were more easily degraded under anaerobic conditions. Crocker et al. (2006) indicated that the mechanisms of high melting explosive and royal demolition explosive biodegradation are similar, but that high melting explosive degrades more slowly. Singh et al. (2009) noted that royal demolition explosive and high melting explosive are biodegraded under a variety of anaerobic conditions by specific microbial species and by mixtures of such species. Zhao et al. (2004a); Zhao et al. (2004b) found that biodegradation of royal demolition explosive and high melting explosive occurs in cold marine sediments.

According to Singh et al. (2009), typical end products of the degradation of royal demolition explosive include nitrite, nitrous oxide, nitrogen, ammonia, formaldehyde, formic acid, and carbon dioxide. Crocker et al. (2006) stated that many of the primary and secondary intermediate compounds from biodegradation of royal demolition explosive and high melting explosive are unstable in water and spontaneously decompose. Thus, these explosives are degraded by a combination of biotic and abiotic reactions. Formaldehyde is subsequently metabolized to formic acid, methanol, carbon dioxide, or methane by various microorganisms (Crocker et al., 2006).

A series of research efforts focused on World War II underwater munitions disposal sites in Hawaii (Briggs et al., 2016; Kelley et al., 2016; Koide et al., 2016) and an intensively used live fire range in the Mariana Islands (Smith & Marx, 2016) provide information in regard to the impacts of undetonated materials and unexploded munitions on marine life.

On a localized scale, research at World War II munitions ocean disposal sites in Hawaii investigated nearby sediments, seawater, or marine life to determine if released constituents from the munitions (including explosive materials and metals) could be detected. Comparisons were made between disposal site samples and "clean" reference sites. Analysis of the samples showed no confirmed detection for explosive materials.

Investigations by Kelley et al. (2016) and Koide et al. (2016) found that intact munitions (i.e., ones that failed to detonate or non-explosive practice munitions) residing in or on soft sediments habitats provided hard substrate similar to other disposed objects or "artificial reefs" that attracted "hard substrate species," which would not have otherwise colonized the area. Sampling these species revealed that there was no bioaccumulation of munitions-related chemicals in the species (Koide et al., 2016).

On a broader scale, the island of Farallon De Medinilla (in the Mariana Islands) has been used as a target area for both explosive and non-explosive munitions since 1971. Between 1997 and 2012, the Navy has conducted 14 underwater scientific surveys around the island, providing a consistent, long-term investigation of a single site where munitions have been used regularly (Smith & Marx, 2016). Marine life assessed during these surveys included algae, corals, benthic invertebrates, sharks, rays, bony fishes, and sea turtles. The investigators found no evidence over the 16-year period, that the condition of the physical or biological resources had been adversely impacted to a significant degree by the training activities (Smith & Marx, 2016). Furthermore, they found that the health, abundance, and biomass of fishes, corals and other marine resources were comparable to or superior to those in similar habitats at other locations within the Mariana Archipelago.

These findings are consistent with other assessments such as that done for the Potomac River Test Range at Dahlgren, Virginia which was established in 1918 and is the nation's largest fully instrumented, over-the-water gun-firing range. Munitions tested at Dahlgren have included rounds from small caliber guns up to the Navy's largest (16 inch guns), bombs, rockets, mortars, grenades, mines, depth charges, and torpedoes (U.S. Department of the Navy, 2013b). Results from the assessment indicate that munitions expended at Dahlgren have not contributed significant concentrations of explosive materials or explosives byproducts to the Potomac River water and sediments given those contributions are orders of magnitude less than concentrations already present in the Potomac River from natural and manmade sources (U.S. Department of the Navy, 2013c).

In summary, multiple investigations since 2007 involving survey and sampling of World War II munition dump sites off Oahu Hawaii and other locations, have found the following: (1) chemicals and degradation products from underwater munitions "do not pose a risk to human health or to fauna living in direct contact with munitions"; (2) metals measured in sediment samples next to World War II munitions are lower than naturally occurring marine levels and "do not cause a significant impact on the environment"; and (3) sediment is not a significant sink of chemicals released by degradation of the explosive components in munitions (Edwards et al., 2016b).

The concentration of explosive munitions and any associated explosives byproducts at any single location in the HSTT Study Area would be a small fraction of the totals that have accumulated over decades at World War II era dump sites and military ranges. Based on findings from much more intensively used locations, effects on sediments from the use of explosive munitions during training and testing activities would be negligible by comparison. As a result, explosives by-products and unexploded munitions would have no meaningful effect on sediments.

Most explosive material is consumed in an explosion, so the vast majority of explosive material entering the marine environment would be encased in munitions that failed to detonate. Failure rates for all of the munitions used in the Proposed Action are not available; however, based on the data that are available, a 5 percent munitions failure rate was applied to estimate failure rates for all munitions used in the Proposed Action. Based on the available data, low-order detonation rates are assumed to be at least an order of magnitude less than failure rates for all munitions and are not considered in the analysis. Table 3.2-10 provides information about the rates of failure and low-order detonations for explosives and other munitions (MacDonald & Mendez, 2005).

Table 3.2-10: Failure and Low-Order Detonation Rates of Military Munitions

Munitions	*Failure Rate (Percent)*	*Low-Order Detonation Rate (Percent)*
Guns/artillery	4.68	0.16
Hand grenades	1.78	n/a
Explosive munitions	3.37	0.09
Rockets	3.84	n/a
Submunitions	8.23	n/a

Note: n/a = not available

Most activities involving explosives and explosives byproducts would be conducted more than 3 NM offshore in each range complex. Activities in these areas (3–200 NM) would be subject to federal sediment and water quality standards and guidelines.

Explosives are also used in nearshore areas (low tide line to 3 NM) specifically designated for mine countermeasure and mine neutralization activities. These activities would be subject to state sediment and water quality standards and guidelines.

For explosives byproducts, "local" refers to the water column in the vicinity of the underwater detonation. For unconsumed explosives, "local" refers to the area of potential impact from explosives in a zone of sediment about 6 ft. in diameter around the unconsumed explosive where it comes to rest on the seafloor.

3.2.3.1.1 Impacts from Explosives and Explosives Byproducts Under Alternative 1

3.2.3.1.1.1 Impacts from Explosives and Explosives Byproducts Under Alternative 1 for Training Activities

The distribution of explosives used in training activities is not uniform throughout the Study Area. Approximately 30 percent of the explosives used annually during training activities would be used in the Hawaii Range Complex, 67 percent used in the Southern California Range Complex, and the remaining 3 percent used in the HSTT transit corridor. Of all explosive munitions used during training activities, approximately 85 percent in the Hawaii Range Complex and 90 percent in the Southern California Range Complex would have a net explosive weight of 2.5 lb. or less per munition. Training activities are further described in Chapter 2 (Description of Proposed Action and Alternatives) and listed in Table 2.3-2 and Table 2.6-1.

The highest concentrations of munitions residues result from munitions failures (i.e., low-order detonations). As a general rule, between 10,000 and 100,000 high-order detonations deposit the same mass of explosives residue as one low-order detonation of the same munition(U.S. Environmental Protection Agency, 2012b). Therefore, an estimate of the amount of explosives material and byproducts from an explosion that would be introduced into the environment is based solely on the failure rate for each type of munition, discounting the negligible contribution from munitions that successfully detonate. The military does not track failure rates for all munitions. The available data typically report failure rates ranging from less than 2 percent up to 10 percent (Table 3.2-10). For the purpose of estimating the amount of explosives and explosives byproducts entering the marine environment, a 5 percent failure rate is applied to all types of munitions used during training activities. The amount of explosive materials is estimated by multiplying the failure rate by the number of explosive munitions and the net explosive weight of each munition used during training activities.

To better organize and facilitate the analysis of different types of explosive munitions, each munition used in training and testing activities was grouped into a series of source classification bins, or source bins (see Section 3.0.3.3.2, Explosive Stressors). Each source bin is defined by a range of net explosive weights (e.g., bin E3 has a range of 0.5 to 2.5 lb. net explosive weight). To estimate the amount of explosive materials entering the marine environment the average net explosive weight was calculated for each source bin. For example, for bin E1 (0.1 to 0.25 lb. net explosive weight) under Alternative 1:

> Explosives = 0.05 (Failure Rate) x 1,600 (Munitions in Bin E1) x 0.175 lb. (Average Net Explosive Weight) = 14 lb.

One other factor needs to be considered when estimating the amount of explosives entering the marine environment in munitions that fail to detonate. The net explosive weight of an explosive munition is based on the equivalent amount of trinitrotoluene (TNT) that would be required to generate the desired amount of energy upon detonation. Most modern munitions no longer use trinitrotoluene (TNT) as the primary explosive material. Other more powerful and stable explosives such as royal demolition explosive are used in a greater number of explosive munitions. Because royal demolition explosive is more powerful than trinitrotoluene (TNT), a lesser amount of royal demolition explosive is needed to generate the equivalent explosion using trinitrotoluene (TNT). The equivalency factors for royal demolition explosive is 1.60, meaning that, to generate an explosion equivalent to 1 kg of trinitrotoluene (TNT) only 0.625 kg of royal demolition explosive is needed. Revising the equation above to incorporate the trinitrotoluene (TNT) equivalency factor:

> Explosives = 0.05 (Failure Rate) x 1,600 (Munitions) x 0.175 lb. (Average Net Explosive Weight) x 0.625 (equivalency factor) = 8.75 lb.

Using this approach, and considering all training activities in the HSTT Study Area, up to approximately 25,000 lb. of explosive material could enter the environment in munitions that failed to detonate. Three fourths, approximately 19,000 lb., would result from 32 munitions (or 5 percent of 725 total munitions) in the E12 bin, which are used at least 3 NM from shore and often more than 12 NM from shore, which diminishes any potential impact on nearshore sediments and water quality.

> Explosives = 0.05 (Failure Rate) x 725 (Munitions) x 825 lb. (Average Net Explosive Weight) x 0.625 (equivalency factor) = 18,691 lb.

Furthermore, munitions would be widely distributed in the offshore OPAREAs and would not accumulate in particular areas, reducing potential impacts on sediments and water quality.

Water depth increases with distance from shore, such that munitions residing on the seafloor at depths greater than approximately 250 m would be in a low light, low temperature environment slowing the corrosion of munitions casings and that degradation of any exposed explosives. Larger projectiles (e.g., missiles, rockets, bombs) used in training activities that fail to detonate would enter the water at a high rate of speed and may become imbedded in soft sediments, depending on water depth and the composition of seafloor substrate. Munitions that are buried partially or completely beneath sediments may remain intact for decades in places where geochemical conditions (e.g., low dissolved oxygen) inhibit corrosion of the metal casing. Studies conducted at several Navy ranges where explosives have been used for decades indicate that explosives constituents are released into the aquatic environment over long periods of time and do not result in water or sediment toxicity (Briggs et al., 2016; U.S. Department of the Navy, 2010a, 2010d, 2013c).

The overarching conclusions from the Hawaii Undersea Military Munitions Assessment project is that degrading munitions at the disposal site do not pose a risk to human health or to the fauna living in direct contact with the degrading munitions (Edwards et al., 2016b). During a comprehensive survey of the site, explosive materials were detected in sediments at only two locations and the concentrations were low. Concentrations of metals introduced into sediments and the water column from deteriorating munitions casings were below screening levels for the marine environment, and the authors concluded that the metals are not impacting the environment.

Data supporting these conclusions were collected from World War II era munitions disposal sites characterized by relatively high concentrations of munitions. Munitions used in the proposed training activities would be widely dispersed by comparison, resulting in lower concentrations of munitions that failed to detonate and lower concentrations of residual explosives and explosives byproducts than reported in Edwards et al. (2016b). Based on this analysis, impacts on sediments and water quality are expected to be minimal and would not adversely affect benthic and water column habitat.

In the event a munition fails to detonate, the explosives contained within the intact munition would remain isolated from the water column and sediments. Based on analyses of munitions disposal sites, explosives would only leach from the munitions casing slowly, over decades, once the munitions casing corrodes and is breached, exposing the explosives to seawater or sediments (Briggs et al., 2016). Small amounts of explosives may leach into sediments and the adjacent water column. In the event the munition fails to detonate but the casing is nevertheless breached upon impact, explosives may enter the water column as the breached munitions sinks to the seafloor. Analysis from munitions disposal sites indicates that munitions constituents and degradation products are only detected at measurable levels in sediments within a few feet of a degrading munition. Many constituents released into the water column would be expected to dissolve (refer to Table 3.2-9 for water solubility) and disperse with ocean currents and would not likely concentrate at levels that would result in water toxicity. Explosives released into sediments from a partially buried munition may persist in sediments or degrade slowly over time if the explosive material or its constituents are not soluble in seawater (e.g., royal demolition explosive). In deepwater (greater than 250 m), benthic habitats, bottom temperatures are near freezing, and dissolved oxygen levels are low (or event anoxic) in sediments only a few inches below the water column-seafloor interface. These physical conditions inhibit degradation and dispersion of the explosives and constituents beyond an isolated area adjacent to the munition. Based on this analysis, impacts on sediments and water quality are expected to be minimal and would not adversely affect benthic and water column habitat.

The sinking exercise activity is likely to result in the highest concentration of munitions of any proposed training or testing activity. During each sinking exercise, for example, an estimated 570 explosive munitions would be expended, 65 percent of which would consist of large-caliber projectiles in the E5 and E8 bins. The remaining explosive munitions are in the E12 and E10 bins. Approximately 4,500 lb. of explosive materials could be released per sinking exercise if the munitions used failed to detonate (i.e., 5 percent of the 570 munitions distributed in the E12, E10, E8, and E5 bins). For the purpose of this example the area encompassing the sinking exercise activity is estimated to be approximately 2 NM^2. Thus, during each sinking exercise, approximately 285 munitions would be used per NM^2, and 2,250 lb. of explosive material per NM^2 would sink to the ocean floor encased within munitions that failed to detonate. During an actual sinking exercise munitions are directed at the target vessel, which occupies an area much smaller than 2 NM^2, and it is likely that a failure rate of less than 5 percent would occur for this type of activity. All Sinking Exercises are conducted at least 50 NM from shore in waters at least 6,000 ft. deep. Based on these conditions and the results of the analysis of munitions degradation rates in the studies described above, which occurred at shallower depths and closer to shore, adverse effects on seafloor sediments and water quality are not expected even in areas where the concentration of munitions is likely to be relatively high.

While the Navy is proposing to conduct three Sinking Exercises per year in the Hawaii Range Complex and one in the Southern California Range Complex under Alternative 1, historically, the Navy has not conducted this activity on an annual basis. The last Sinking Exercise conducted in the Pacific was in July 2016 (Table 3.2-11).

Table 3.2-11: Sinking Exercises in the HSTT Study Area Since 2006

Location	*Date*
HRC	July 2006
HRC	November 2006
HRC	July 2008
SOCAL	October 2008
HRC	July 2010
HRC	July 2012
HRC	July 2014
HRC	July 2016

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California Range Complex

3.2.3.1.1.2 Impacts from Explosives and Explosives Byproducts Under Alternative 1 for Testing Activities

The distribution of explosives used in testing activities is not uniform throughout the Study Area. Less than 30 percent of the explosives used annually during testing activities would be expended in the Hawaii Range Complex, with the remainder (over 70 percent) expended in the Southern California Range Complex. Approximately 70 percent of the explosives expended in the Southern California Range Complex would be medium caliber ammunition with a net explosive weight between 0.1 and 0.25 lb. In the Hawaii Range Complex, approximately 85 percent of explosives would have a net explosive weight of less than 10 lb.

As described for training activities in Section 3.2.3.1.1.1 (Impacts from Explosives and Explosives Byproducts Under Alternative 1 for Training Activities), over 98 percent of explosives byproducts introduced into the environment would result from the failure of a munition to detonate, because little to no explosive material remains after a successful detonation. The amount of residual explosives materials resulting from testing activities is estimated in the same way it was estimated for training activities: by multiplying the failure rate by the number of explosive munitions and the average net explosive weight for the bin in which each explosive munitions is classified.

For all testing activities in the HSTT Study Area, up to 1,100 lb. of explosive material would enter the environment annually in munitions that failed to detonate. In the event of a munition fails to detonate, the explosives would remain mostly intact and contained within the munitions casing, which is composed mostly of iron with smaller quantities of other metals. Explosive materials would only leach from the casing slowly, over years, as the casing corrodes and degrades. Once exposed to the environment, explosives materials are quickly broken down into constituent materials (Briggs et al., 2016). Ocean currents would quickly disperse constituents entrained into the water column. Chemical constituents that settle onto sediments in the immediate vicinity of the munition are likely to persist in the environment due to a combination of low water solubility (Table 3.2-9), the products of hydrolysis forming a coating that prevents further decomposition, and near freezing temperatures at deepwater sites that typically inhibit chemical dissolution (Briggs et al., 2016).

Larger projectiles used in testing activities that fail to detonate would enter the water at a high rate of speed and may become imbedded in soft sediments, depending on water depth and the composition of seafloor substrate. Munitions buried partially or completely beneath sediments may remain intact for decades in places where geochemical conditions (e.g., low dissolved oxygen) inhibit corrosion of the metal casing. Studies conducted at several Navy ranges where explosives have been used for decades indicate that explosives constituents are released into the aquatic environment over long periods of time and do not result in water or sediment toxicity (Briggs et al., 2016; U.S. Department of the Navy, 2010a, 2010d, 2013c). Based on the results from studies of underwater munitions disposal sites and water ranges, impacts on sediments and water quality are expected to be minimal and localized.

The overarching conclusions from the Hawaii Undersea Military Munitions Assessment project is that degrading munitions at the disposal site do not pose a risk to human health or to the fauna living in direct contact with the degrading munitions (Edwards et al., 2016b). During a comprehensive survey of the site, explosive materials were detected in sediments at only two locations and the concentrations were low. Concentrations of metals introduced into sediments and the water column from deteriorating munitions casings were below screening levels for the marine environment, and the authors concluded that the metals are not impacting the environment.

Data supporting these conclusions were collected from World War II era munitions disposal sites characterized by relatively high concentrations of munitions. Munitions used in the proposed testing activities would be widely dispersed by comparison, resulting in lower concentrations of munitions that failed to detonate and lower concentrations of residual explosives and explosives byproducts than reported in Edwards et al. (2016b). Based on this analysis, impacts on sediments and water quality are expected to be minimal and would not adversely affect benthic and water column habitat.

3.2.3.1.2 Impacts from Explosives and Explosives Byproducts Under Alternative 2

3.2.3.1.2.1 Impacts from Explosives and Explosives Byproducts Under Alternative 2 for Training Activities

Under Alternative 2, the Navy would conduct 20 Sinking Exercises over five years (compared to just 8 under Alternative 1). The number of training events that would be conducted under Alternative 2 is shown in Table 2.6-1 in Chapter 2 (Description of Proposed Action and Alternatives). As described above, conducting additional sinking exercises would introduce a substantial amount of metals into the marine benthic environment. The sunken vessel would reside on the seafloor at a depth of at least 6,000 ft. where temperatures are constantly near freezing and dissolved oxygen content in water and sediments is low, conditions that slow the corrosion process (refer back to Section 3.2.3.3, Metals). The additional sinking exercises would use approximately 1,700 more explosive munitions, including 960 explosives in the E5 bin, over 150 each in the E8 and E10 bins, and over 430 in the E12 bin over five years. The increase in the number of explosives would result in approximately 14,000 lb. of additional explosives materials residing in munitions that failed to detonate, based on a 5 percent failure rate. While the potential impact to sediments would be greater than under Alternative 1, the additional explosives would be subject to the same slow degradation rates expected to occur in the deepwater environment limiting the impact to sediments that are immediately adjacent to undetonated munitions (see Section 3.2.3.1 (Explosives and Explosives Products) and Section 3.2.3.1.1.1 [Impacts from Explosives and Explosives Byproducts Under Alternative 1 for Training Activities] for additional discussion). Based on this analysis, impacts on sediments and water quality are expected to be minimal and would not adversely affect benthic and water column habitat.

3.2.3.1.2.2 Impacts from Explosives and Explosives Byproducts Under Alternative 2 for Testing Activities

Under Alternative 2, the number of explosive munitions used during testing activities would increase, resulting in approximately 180 lb. of additional explosives materials potentially entering the marine environment in munitions that failed to detonate. However, approximately 108 lb. of the 180 lb. of additional explosives are from mines in the E11 bin. If these mines failed to detonate during the testing activity as planned, they would be detonated on-site by other means and would not be permitted to remain as undetonated munitions in the environment. Based on the analysis presented above in Section 3.2.3.1.1.2 (Impacts from Explosives and Explosives Byproducts Under Alternative 1 for Testing Activities), the additional explosives materials would not measurably impact sediments and water quality in the Study Area. Therefore, the impacts of explosives and explosives byproducts would be approximately the same as described under Alternative 1.

3.2.3.1.3 Impacts from Explosives and Explosives Byproducts Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Explosives and explosive byproducts would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.2.3.2 Chemicals Other Than Explosives

Under the Proposed Action, chemicals other than explosives are associated with the following military expended materials: (1) solid-fuel propellants in missiles and rockets; (2) Otto Fuel II torpedo propellant and combustion byproducts; (3) polychlorinated biphenyls in target vessels used during sinking exercises; (4) other chemicals associated with munitions; and (5) chemicals that simulate chemical warfare agents, referred to as “chemical simulants.”

Hazardous air pollutants from explosives and explosives byproducts are discussed in Section 3.1 (Air Quality). Explosives and explosives byproducts are discussed in Section 3.2.3.1 (Explosives and Explosives Byproducts). Fuels onboard manned aircraft and vessels are not reviewed, nor are fuel-loading activities, onboard operations, or maintenance activities reviewed, because normal operation and maintenance of Navy equipment is not part of the Proposed Action.

The largest chemical constituent of missiles is solid propellant. Solid propellant contains both the fuel and the oxidizer, a source of oxygen needed for combustion. An extended-range Standard Missile-2 typically contains 1,822 lb. of solid propellant. Ammonium perchlorate is the oxidizing agent used in most modern solid-propellant formulas (Chaturvedi & Dave, 2015). It normally accounts for 50 to 85 percent of the propellant by weight. Ammonium dinitramide may also be used as an oxidizing agent. Aluminum powder as a fuel additive ranges from 5 to 22 percent by weight of solid propellant; it is added to increase missile range and payload capacity. The explosives high melting explosive (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) and royal demolition explosive (hexahydro-1,3,5-trinitro-

1,3,5-triazine) may be added, although they usually comprise less than 30 percent of the propellant by weight. Many of the constituents used in propellants are also commonly used for commercial purposes but require additional processing to achieve certain properties necessary for rocket and missile propulsion. (Missile Technology Control Regime, 1996).

The USEPA issued a paper characterizing the munitions constituents accumulated at over 30 military sites around the United States and Canada where explosives and propellants have been used (U.S. Environmental Protection Agency, 2012b). The sites assessed in the paper were all land-based ranges; however, the results are useful for analyzing similar activities conducted at sea. The paper noted that perchlorate was generally not detected at anti-tank ranges and that perchlorate is so soluble in water and mobile in soil that surface accumulation apparently does not occur. The paper includes a case study that estimates the amount of residual perchlorate deposited from a rocket fired at a test track. The rocket propellant contained 68 lb. of ammonium perchlorate. Samples were collected both behind the firing point and along the test track before and after the rocked was fired. No differences in perchlorate concentrations in soils were detected at any location before or after the firing, and all measurements recorded perchlorate concentrations of less than 1 μg/kg. That case study concluded that 99.997 percent of perchlorate is consumed by the rocket motor (U.S. Environmental Protection Agency, 2012b). Fitzpatrick et al. (2006) found similar results from an air-launched AIM-7 missile, a missile used by the Navy and similar to missiles used in the Proposed Action. These studies, and others cited in each paper, demonstrate that the motors used in rockets and missiles are highly efficient at burning propellant fuels, leaving only trace amounts often at undetectable levels in the environment.

Several torpedoes (e.g., MK-54) use Otto Fuel II as a liquid propellant. Otto Fuel II is composed of primarily three synthetic substances: Propylene glycol dinitrate and nitro-diphenylamine (76 percent), dibutyl sebacate (22 percent), and 2-nitrodiphenylamine as a stabilizer (2 percent). Propylene glycol dinitrate, which is a liquid, is the explosive component of Otto Fuel II. Dibutyl sebacate, also known as sebacic acid, is also a liquid. It is used commercially to make plastics, many of which are used for packaging food, and to enhance flavor in foods such as ice cream, candy, baked goods, and nonalcoholic drinks. The third component, 2-nitrodiphenylamine, is a solid substance used to control the combustion of the propylene glycol dinitrate (Espinoza & Wehrtmann, 2008). Combustion byproducts of Otto Fuel II include nitrous oxides, carbon monoxide, carbon dioxide, hydrogen, nitrogen, methane, ammonia, and hydrogen cyanide. During normal venting of excess pressure or upon failure of the torpedo's buoyancy bag, the following constituents are discharged: carbon dioxide, water, hydrogen, nitrogen, carbon monoxide, methane, ammonia, hydrochloric acid, hydrogen cyanide, formaldehyde, potassium chloride, ferrous oxide, potassium hydroxide, and potassium carbonate (Waters et al., 2013).

Target vessels are only used during sinking exercises, which occur infrequently. Polychlorinated biphenyls are a concern because they are present in certain solid materials (e.g., insulation, wires, felts, and rubber gaskets) on vessels used as targets for sinking exercises. These vessels are selected from a list of Navy-approved vessels that have been cleaned in accordance with USEPA guidelines (U.S. Environmental Protection Agency, 2014). By rule, a sinking exercise must be conducted at least 50 NM offshore and in water at least 6,000 ft. deep (40 CFR 229.2).

The U.S. Environmental Protection Agency estimates that as much as 100 lb. of polychlorinated biphenyls remain onboard sunken target vessels. The USEPA considers the contaminant levels released during the sinking of a target to be within the standards of the Marine Protection, Research, and Sanctuaries Act (16 U.S.C. 1341, et seq.) (U.S. Environmental Protection Agency, 2014). Under the 2014 agreement with the USEPA, the Navy will not likely use aircraft carriers or submarines as the targets for a sinking exercise (U.S. Environmental Protection Agency, 2014). Based on these considerations, polychlorinated biphenyls will not be considered further.

Table 3.2-12 lists the chemical constituents produced in the combustion of propellants and fuels, as described above, and list constituents remaining after the detonations of non-munitions, such as spotting charges and tracers. Not all of the listed chemical constituents in propellant and Otto Fuel II would be used in combination; some are substitutes that would replace another chemical in the list, depending on the type of propellant used. For example, ammonium perchlorate is the preferred oxidizer in propellant, but ammonium dinitramide could act as the oxidizer in some propellants. These constituents are in addition to the explosives contained in munitions, which were discussed in Section 3.2.3.1 (Explosives and Explosives Byproducts).

Table 3.2-12: Constituents in Munitions Other Than Explosives

Munitions Component	*Constituent*
Pyrotechnics Tracers Spotting Charges	Barium chromate Potassium perchlorate Chlorides Phosphorus Titanium compounds
Oxidizers	Lead (II) oxide
Propellant (rockets and missiles)	Ammonium perchlorate (50 to 85 percent by weight) Ammonium dinitramide Aluminum powder (5 to 21 percent by weight) High melting explosive Royal demolition explosive Hydroxyl-terminated polybutadiene Carboxyl-terminated polybutadiene Polybutadiene-acrylic acid-acrylonitrile Triphenyl bismuth Nitrate esters Nitrated plasticizers Polybutadiene-acrylic acid polymer Elastomeric polyesters Polyethers Nitrocellulose plasticized with nitroglycerine 2-nitrodiphenylamine N-methyl-4-nitroaniline Hydrazine

Table 3.2-12: Constituents in Munitions Other Than Explosives (continued)

Munitions Component	*Constituent*
Otto Fuel II (torpedoes)	Propylene glycol dinitrate and Nitro-diphenylamine (76 percent by weight) dibutyl sebacate (22 percent by weight) 2-nitrodiphenylamine (2 percent by weight) Combustion products (nitrous oxides, carbon monoxide, carbon dioxide, hydrogen, nitrogen, methane, ammonia, hydrogen cyanide) Venting or buoyancy bag failure (hydrochloric acid, hydrogen cyanide, formaldehyde, potassium chloride, ferrous oxide, potassium hydroxide, and potassium carbonate)
Chemical Simulants	Navy Chemical Agent Simulant 82 glacial acetic acid triethyl phosphate sulfur hexafluoride 1,1,1,2 tetrafluoroethane 1,1-difluoroethane
Delay Elements	Barium chromate Potassium perchlorate Lead chromate
Fuses	Potassium perchlorate
Detonators	Fulminate of mercury Potassium perchlorate
Primers	Lead azide

The environmental fate of Otto Fuel II and its components is largely unknown. Neither the fuel mixture nor its three main components are particularly volatile or soluble in water; however, when mixed with water propylene glycol dinitrate forms a volatile mixture, making evaporation an important fate process (Espinoza & Wehrtmann, 2008). The compound 2-Nitrodiphenylamine may precipitate from water or be taken up by particulates. Dibutyl sebacate is rapidly biodegraded. Neither propylene glycol dinitrate nor 2-nitrodiphenylamine are readily biodegradable, but both of these chemicals break down when exposed to ultraviolet light (Powell et al., 1998).

Lead azide, titanium compounds, perchlorates, barium chromate, and fulminate of mercury are not natural constituents of seawater. Lead oxide is a rare, naturally occurring mineral. It is one of several lead compounds that form films on lead objects in the marine environment (Agency for Toxic Substances and Disease Registry, 2007). Metals are discussed in more detail in Section 3.2.3.3 (Metals).

Because chemical and biological warfare agents remain a security threat, the Department of Defense uses relatively harmless compounds (chemical simulants) as substitutes for chemical and biological warfare agents to test equipment intended to detect their presence. Chemical and biological agent detectors monitor for the presence of chemical and biological warfare agents and protect military personnel and civilians from the threat of exposure to these agents. The simulants trigger a response by sensors in the detection equipment without irritating or injuring personnel involved in testing detectors.

Navy Chemical Agent Simulant 82 (commonly referred to as NCAS-82), glacial acetic acid, triethyl phosphate, sulfur hexafluoride, 1,1,1,2 tetrafluoroethane (a refrigerant commonly known as R134), and 1,1-difluoroethane (a refrigerant commonly known as R-152a) are also referred to as gaseous simulants and can be released in smaller quantities in conjunction with glacial acetic acid or triethyl phosphate releases. The types of biological simulants that may be used include spore-forming bacteria, non-spore-forming bacteria, ovalbumin, bacteriophage MS2, and *Aspergillus niger*. The simulants are generally dispersed by hand at the detector or by aircraft as a fine mist or aerosol. The exposure of military personnel or the public to even small amounts of real warfare agents, such as nerve or blistering agents, or harmful biological organisms, such as anthrax, is potentially harmful and is illegal in most countries, including the United States. Furthermore, their use, including for the testing of detection equipment, is banned by international agreement.

Simulants must have one or more characteristic of a real chemical or biological agents—size, density, or aerosol behavior—to effectively mimic the agent. Simulants must also pose a minimal risk to human health and the environment to be used safely in outdoor tests. Simulants are selected using the following criteria: (1) safety to humans and the environment, and (2) the ability to trigger a response by sensors used in the detection equipment. Simulants must be relatively benign (e.g., low toxicity or effects potential) from a human health, safety, and environmental perspective. Exposure levels during testing activities should be well below concentrations associated with any adverse human health or environmental effects. The degradation products of simulants must also be harmless. Given these criteria for choosing simulants for use in testing activities, it is reasonable to conclude that simulants would have no impact on sediments and water quality in the Study Area. Simulants are not analyzed further in this section.

3.2.3.2.1 Impacts from Chemicals Other Than Explosives Under Alternative 1

3.2.3.2.1.1 Impacts from Chemicals Other Than Explosives Under Alternative 1 for Training Activities

The distribution of munitions that use chemicals other than explosives is not uniform throughout the Study Area. Under Alternative 1, chemicals other than explosives would be associated with several types of munitions used during training activities (see Section 3.2.3.2, Chemicals Other Than Explosives). The largest quantities of chemicals would be expended from the use of propellants and fuels, particularly the Otto Fuel II used by torpedoes. Approximately 67 percent of these munitions are rockets (expending the byproducts of propellant combustion) used in the Southern California portion of the HSTT Study Area. Missiles make up another 4 percent of these munitions. The propellant used by rockets and missiles is typically consumed prior to impact at the water’s surface even if the munition fails to detonate upon impact, leaving little residual propellant to enter the water.

Over 500 torpedoes using Otto Fuel II would be used annually. Torpedo fuel is consumed underwater and all combustion products enter the marine environment. The number of torpedoes that would be used during testing activities is approximately the same in the Hawaii Range Complex and the Southern California portion of the HSTT Study Area. All practice torpedoes would be recovered after testing activities, which would reduce the exposure of residual amounts of Otto Fuel II to the marine environment.

For properly functioning munitions, chemical, physical, or biological changes in sediments or water quality would not be detectable. Impacts would be minimal for the following reasons: (1) the size of the area in which expended materials would be distributed is large; (2) most propellant combustion byproducts are benign, while those of concern would be diluted to below detectable levels within a short time; (3) most propellants are consumed during normal operations; (4) most byproducts of Otto Fuel II combustion are naturally occurring chemicals, and most torpedoes are recovered after use, such that any fuel that is not consumed would be recovered along with the torpedo, limiting any direct exposure of sediments and water to Otto Fuel II; (5) the failure rate of munitions using propellants and other combustible materials is low; and (6) most of the constituents of concern are biodegradable by various marine organisms or by physical and chemical processes common in marine ecosystems.

3.2.3.2.1.2 Impacts from Chemicals Other Than Explosives Under Alternative 1 for Testing Activities

The distribution of munitions that use chemicals other than explosives is not uniform throughout the Study Area. Under Alternative 1, chemicals other than explosives would be associated with several types of munitions used during testing activities (see Section 3.2.3.2, Chemicals Other Than Explosives). The largest quantities of chemicals would be expended from the use of propellants and fuels, particularly the Otto Fuel II used by torpedoes. Approximately 25 percent of these munitions are rockets and missiles (expending the byproducts of propellant combustion). The propellant used by rockets and missiles is typically consumed prior to impact at the water's surface even if the munition fails to detonate upon impact, leaving little residual propellant to enter the water. Over 800 torpedoes using Otto Fuel II would be used annually and distributed equally between the Hawaii Range Complex and the Southern California portion of the HSTT Study Area. Torpedo fuel is consumed underwater and all combustion products enter the marine environment. All practice torpedoes would be recovered after testing activities, which would reduce the exposure of residual amounts of Otto Fuel II to the marine environment. The Navy also tests chemical and biological simulants. As described in Section 3.2.3.2 (Chemicals Other Than Explosives), chemical and biological simulants are benign and would have no impact on sediments and water quality

For properly functioning munitions items, chemical, physical, or biological changes in sediments or water quality would not be detectable. Impacts would be minimal for the following reasons: (1) the size of the area in which expended materials would be distributed is large; (2) most propellant combustion byproducts are benign, while those of concern would be diluted to below detectable levels within a short time; (3) most propellants are consumed during normal operations; (4) most byproducts of Otto Fuel II combustion are naturally occurring chemicals, and most torpedoes are recovered after use, such that any fuel that is not consumed would be recovered along with the torpedo, limiting any direct exposure of sediments and water to Otto Fuel II; (5) the failure rate of munitions using propellants and other combustible materials is low; and (6) most of the constituents of concern are biodegradable by various marine organisms or by physical and chemical processes common in marine ecosystems.

3.2.3.2.2 Impacts from Chemicals Other Than Explosives Under Alternative 2

3.2.3.2.2.1 Impacts from Chemicals Other Than Explosives Under Alternative 2 for Training Activities

Under Alternative 2, the number of expended munitions propellants (missiles and rockets) and Otto Fuel II (torpedoes) would increase compared to the number used under Alternative 1. Additional missiles and torpedoes would be used as part of the sinking exercise activity, resulting in the use of more propellant and Otto Fuel II. The propellant used by missiles is typically consumed prior to impact at the water's surface even if the munition fails to detonate upon impact, leaving little residual propellant to enter the water. The use of approximately 150 missiles over five years would not result in the accumulation of any additional propellant or propellant byproducts (see Section 3.2.3.2, Chemicals Other Than Explosives). Similarly, the use of fewer than 30 additional torpedoes over five years would not result in the accumulation of byproducts of Otto Fuel II in water or sediments. The amounts of other expended materials that could release chemicals into the marine environment would be similar to the amounts under Alternative 1. Therefore, the release of chemicals derived from propellants and fuels would have the approximately same environmental impacts as described under Alternative 1.

3.2.3.2.2.2 Impacts from Chemicals Other Than Explosives Under Alternative 2 for Testing Activities

The number of munitions that use propellants (rockets and missiles) and Otto Fuel II (torpedoes) annually would increase under Alternative 2. Over a 5-year period, an additional 200 rockets would be used during testing activities. Because rocket motors are over 99 percent efficient at burning propellant, no additional measurable amounts of propellant or combustion products would enter the water column. The amounts of other expended materials that could release chemicals into the marine environment would be similar to the amounts under Alternative 1. Therefore, the release of chemicals derived from propellants and fuels would have the approximately same environmental impacts as described under Alternative 1.

3.2.3.2.3 Impacts from Chemicals Other Than Explosives Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Chemicals other than explosives would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities. Based on the studies by Wang et al. (2014a), fewer vessel movements, particularly of larger vessels, in the shallower parts of Pearl Harbor and San Diego Bay would likely reduce sediment resuspension and dispersion of any sediment contaminants into other parts of Pearl Harbor and San Diego Bay. Under the No Action Alternative, the potential for resuspension and redistribution of sediments with contaminants may be reduced in Pearl Harbor and San Diego Bay. However, it is unclear if reducing vessel movement in shallow water would have a measurable effect on sediment and water quality in Pearl Harbor and San Diego Bay, because other sources of resuspension (e.g., other vessels, heavy riverine inflow) would still occur and no net increase in sediment contaminants is caused by vessel movements.

3.2.3.3 Metals

Anthropogenic sources of metals include the processing of industrial ores (e.g., iron ore), production of chemicals, fertilizers used in agriculture, the marine industry (e.g., anti-fouling anti-corrosion paints), runoff from urban and suburban sprawl, dredge spoil disposal, exhaust from automotive transportation, atmospheric deposition, and industrial emissions (Haugland et al., 2006). Metals would be introduced into nearshore and offshore marine waters and sediments by the Proposed Action. Because of the physical and chemical reactions that occur with metals in marine systems, many metals will precipitate out of seawater and settle in solid form on the seafloor where they can concentrate in sediments. Thus, metal contaminants in sediments pose a greater environmental concern than metals in the water column.

Military expended materials such as steel bomb bodies or fins, missile casings, small arms projectiles, and naval gun projectiles may contain small percentages (less than 1 percent by weight) of lead, manganese, phosphorus, sulfur, copper, nickel, tungsten, chromium, molybdenum, vanadium, boron, selenium, columbium, or titanium. Small-caliber projectiles are composed of steel with small amounts of aluminum and copper and brass casings that are 70 percent copper and 30 percent zinc. Medium- and large-caliber projectiles are composed of steel, brass, copper, tungsten, and other metals. The 20 mm cannon shells used in close-in weapons systems are composed mostly of tungsten alloy. Some projectiles have lead cores (U.S. Department of the Navy, 2008a). Torpedo guidance wire is composed of copper and cadmium coated with plastic (U.S. Department of the Navy, 2008b). Sonobuoy components include batteries and battery electrodes, lead solder, copper wire, and lead used for ballast. Thermal batteries in sonobuoys are contained in an airtight, sealed and welded stainless steel case that is 0.03-0.1 in. thick and resistant to the battery electrolytes (U.S. Department of the Navy, 2008a). Rockets are usually composed of steel and steel alloys, although composite cases made of glass, carbon, or Kevlar fiber are also used (Missile Technology Control Regime, 1996). Anchors used to moor mine shapes or other seafloor devices are often recovered but in some cases may be left on the seafloor to facilitate recovery of the device (refer to Section 3.0, Introduction). Metal anchors and other types of anchors (e.g., concrete blocks) with metal components are composed primarily of steel.

Non-explosive practice munitions consist of ammunition and components that contain no explosive material, and may include (1) ammunition and components that have had all explosive material removed and replaced with non-explosive material, (2) empty ammunition or components, and (3) ammunition or components that were manufactured with non-explosive material in place of all explosive material. These practice munitions vary in size from 25 to 500 lb. and are designed to simulate the characteristics of explosive munitions for training and testing activities. Some non-explosive practice munitions may also contain unburned propellant (e.g., rockets), and some may contain spotting charges or signal cartridges for locating the point of impact (e.g., smoke charges for daylight spotting or flash charges for night spotting) (U.S. Department of the Navy, 2010d). Large, non-explosive bombs—also called “practice” or “bomb dummy units”—are composed mainly of iron and steel casings filled with sand, concrete, or vermiculite. These materials are similar to those used to construct artificial reefs. Non-explosive bombs are configured to have the same weight, size, center of gravity, and ballistics as explosive bombs (U.S. Department of the Navy, 2006a). Practice bombs do not contain the explosive materials.

Decommissioned vessels used as targets for sinking exercises are selected from a list of U.S. Navy-approved vessels that have been cleaned or remediated in accordance with USEPA guidelines. By rule, vessel-sinking exercises must be conducted at least 50 NM offshore and in water at least 6,000 ft. deep (40 CFR part 229.2). The USEPA requires the contaminant levels released during the sinking of a target to be within the standards of the Marine Protection, Research, and Sanctuaries Act (16 U.S.C. 1341, et seq.).

In general, three things happen to materials that come to rest on the ocean floor: (1) they lodge in sediments where there is little or no oxygen below 4 in., (2) they remain on the ocean floor and begin to react with seawater, or (3) they remain on the ocean floor and become encrusted by marine organisms. As a result, rates of deterioration depend on the metal or metal alloy and the conditions in the immediate marine and benthic environment. If buried deep in ocean sediments, materials tend to decompose at much lower rates than when exposed to seawater (Ankley, 1996). With the exception of torpedo guidance wires and sonobuoy components, sediment burial appears to be the fate of most munitions used in marine warfare (Environmental Sciences Group, 2005).

When metals are exposed to seawater, they begin to slowly corrode, a process that creates a layer of corroded material between the seawater and uncorroded metal. This layer of corrosion removes the metal from direct exposure to the corrosiveness of seawater, a process that further slows movement of the metals into the adjacent sediments and water column. This is particularly true of aluminum. Elevated levels of metals in sediments would be restricted to a small zone around the metal, and any release to the overlying water column would be diluted. In a similar fashion, as materials become covered by marine life, both the direct exposure of the material to seawater and the rate of corrosion decrease. Dispersal of these materials in the water column is controlled by physical mixing and diffusion, both of which tend to vary with time and location. The analysis of metals in marine systems begins with a review of studies involving metals used in military training and testing activities that may be introduced into the marine environment.

In one study, the water was sampled for lead, manganese, nickel, vanadium, and zinc at a shallow bombing range in Pamlico Sound (estuarine waters of North Carolina) immediately following a training event with non-explosive practice bombs. All water quality parameters tested, except nickel, were within the state limits. The nickel concentration was significantly higher than the state criterion, although the concentration did not differ significantly from the control site located outside the bombing range. The results suggest that bombing activities were not responsible for the elevated nickel concentrations (U.S. Department of the Navy, 2010d). A recent study conducted by the U.S. Marine Corps sampled sediments and water quality for 26 different constituents, including lead and magnesium, related to munitions at several U.S. Marine Corps water-based training ranges. These areas also were used for bombing practice. No munitions constituents were detected above screening values used at the U.S. Marine Corps water ranges (U.S. Department of the Navy, 2010d).

A study by Pait et al. (2010) of previous Navy training areas at Vieques, Puerto Rico, found generally low concentrations of metals in marine sediments. Areas in which live ammunition and loaded weapons were used ("live-fire areas") were included in the analysis. These results are relevant because the concentrations of expended munitions at Vieques are significantly greater than would be found anywhere in the HSTT Study Area. Table 3.2-13 compares the sediment concentrations of several metals from those naval training areas with sediment screening levels established by the National Oceanic and Atmospheric Administration (Buchman, 2008).

As shown in Table 3.2-13, average sediment concentrations of the metals evaluated, except for copper, were below both the threshold and probable effects levels (metrics similar to the effects range levels). The average copper concentration was above the threshold effect level, but below the probable effect level. For other elements: (1) the mean sediment concentration of arsenic at Vieques was 4.37 micrograms per gram (µg/g), and the highest concentration was 15.4 µg/g. Both values were below the sediment quality guidelines examined; and (2) the mean sediment concentration of manganese in sediment was 301 µg/g, and the highest concentration was 967 µg/g (Pait et al., 2010). The National Oceanic and Atmospheric Administration did not report threshold or probable effects levels for manganese.

The impacts of lead and lithium were studied at the Canadian Forces Maritime Experimental and Test Ranges near Nanoose Bay, British Columbia, Canada (Environmental Sciences Group, 2005). These materials are common to expendable mobile anti-submarine warfare training targets, acoustic device countermeasures, sonobuoys, and torpedoes. The study noted that lead is a naturally occurring metal in the environment and that typical concentrations of lead in seawater in the test range were between 0.01 and 0.06 parts per million (ppm), while concentration of lead in sediments was between 4 and 16 ppm. Cores of marine sediments in the test range show a steady increase in lead concentration from the bottom of the core to a depth of approximately 8 in. (20.3 cm). This depth corresponds to the late 1970s and early 1980s, and the lead contamination was attributed to atmospheric deposition of lead from gasoline additives. The sediment cores showed a general reduction in lead concentration to the present time, coincident with the phasing out of lead in gasoline by the mid-1980s. The study also noted that other training ranges have shown minimal impacts of lead ballasts because they are usually buried deep in marine sediments where they are not biologically available. The study concluded that the lead ballasts would not adversely impact marine organisms because of the low probability of mobilization of lead.

Table 3.2-13: Concentrations of and Screening Levels for Selected Metals in Marine Sediments, Vieques, Puerto Rico

Metal	*Sediment Concentration (µg/g)*			*Sediment Guidelines – National Oceanic and Atmospheric Administration (µg/g)*	
	Minimum	*Maximum*	*Average*	*Threshold Effects Level**	*Probable Effects Level**
Cadmium	0	1.92	0.15	0.68	4.21
Chromium	0	178	22.5	52.3	160
Copper	0	103	25.9	18.7	390
Lead	0	17.6	5.42	30.24	112
Mercury	N/R	0.112	0.019	130	700
Nickel	N/R	38.3	7.80	15.9	42.8
Zinc	N/R	130	34.4	124	271

Notes: N/R = not reported, µg/g = micrograms per gram

*Threshold Effects Level and Probable Effects Level are metrics similar to the effects range metrics (i.e., Effects Range Low and Effects Range Median) used to assess potential effects of contaminants on sediments. The Threshold Effects Levels is the average of the 50th percentile and the 15th percentile of a dataset and the Probable Effects Level is the average of the 50th percentile and the 85th percentile of a dataset.

A study by the Navy examined the impacts of materials from activated seawater batteries in sonobuoys that freely dissolve in the water column (e.g., lead, silver, and copper ions), as well as nickel-plated steel housing, lead solder, copper wire, and lead shot used for sonobuoy ballast (U.S. Department of the Navy, 1993). The study concluded that constituents released by saltwater batteries as well as the decomposition of other sonobuoy components did not exceed state or federal standards, and that the reaction products are short-lived in seawater.

A series of research efforts focused on World War II underwater munitions disposal sites in Hawaii (Briggs et al., 2016; Kelley et al., 2016; Koide et al., 2016; University of Hawaii, 2010) and an intensively used live fire range in the Mariana Islands (Smith & Marx, 2016) provide information in regard to the impacts of undetonated materials and unexploded munitions on marine life.

On a localized scale, research at World War II munitions ocean disposal sites in Hawaii investigated nearby sediments, seawater, or marine life to determine if metals could be detected. For metals, although there were localized elevated levels of arsenic and lead in several biota samples and in the sediment adjacent to the munitions, the origin of those metals could not be definitively linked to the munitions since comparison of sediment between the clean reference site and the disposal site showed relatively little difference. This was especially the case for a comparison with samples for ocean disposed dredge spoils sites (locations where material taken from the dredging of harbors on Oahu was disposed). At individual sampling sites adjacent to munitions, the concentrations of metals were not significantly higher as compared to the background at control sites and not significant in comparison to typical deep-sea marine sediments (Briggs et al., 2016). Observations and data collected also did not indicate any adverse impact to the localized ecology due to the presence of munitions degrading for over 75 years when compared to control sites. When specifically looking at marine organisms around the munitions (Kelley et al., 2016; Koide et al., 2016), the analysis indicated that in soft bottom habitats the expended items were providing hard substrate similar to other disposed objects or "artificial reefs" that attracted "hard substrate species" that would not have otherwise colonized the area and that there was no bioaccumulation of munitions-related chemicals for the species sampled (Koide et al., 2016).

On a broader scale, the island of Farallon de Medinilla (in the Mariana Islands) has been used as a target area since 1971. Between 1997 and 2012, there were 14 underwater scientific survey investigations around the island providing a long-term look at potential impacts on the marine life from training and testing involving the use of munitions (Smith & Marx, 2016). Munitions use has included explosive rounds from gunfire, high explosive bombs by Navy aircraft and U.S. Air Force B-52s, in addition to the expenditure of inert rounds and non-explosive practice bombs. Marine life assessed during these surveys included algae, corals, benthic invertebrates, sharks, rays, bony fishes, and sea turtles. The investigators found no evidence over the 16-year period, that the condition of the biological resources had been adversely impacted to a significant degree by the training activities (Smith & Marx, 2016). Furthermore, they found that the health, abundance, and biomass of fishes, corals, and other marine resources were comparable to or superior to those in similar habitats at other locations within the Mariana Archipelago.

These findings are consistent with other assessments such as those performed for the Potomac River Test Range at Dahlgren, Virginia which was established in 1918 and is the nation's largest fully instrumented, over-the-water gun-firing range. Munitions tested at Dahlgren have included rounds from small-caliber guns up to the Navy's largest (16 in. guns), along with bombs, rockets, mortars, grenades, mines, depth charges, and torpedoes (U.S. Department of the Navy, 2013c). Results from the assessment indicate that munitions expended at Dahlgren have not contributed significant concentrations of metals to the Potomac River and that the concentrations of metals in local sediments are orders of magnitude lower than in other areas of the Potomac River where metals are introduced from natural and other manmade sources. (U.S. Department of the Navy, 2013c).

The concentrations of metals from munitions, expended materials, and devices in any one location in the HSTT Study Area would be a small fraction of that from a World War II era munitions disposal site, or a target island used for 45 years, or a water range in a river used for almost 100 years. Based on findings from much more intensively used locations, the water quality effects from the use of munitions, expended materials, and other devices resulting from any of the proposed training and testing activities would be negligible by comparison.

3.2.3.3.1 Impacts from Metals Under Alternative 1

3.2.3.3.1.1 Impacts from Metals Under Alternative 1 for Training Activities

Many activities included in the Proposed Action would involve the expenditure of munitions and other military expended materials with metal components. Refer to Chapter 2 (Description of Proposed Action and Alternatives) for information on training activities and their frequency of annual occurrence under Alternative 1 and Appendix A (Navy Activity Descriptions) for a detailed description of munitions and other military expended materials that would be used during training activities.

The distribution of non-explosive munitions and other expended materials composed of or containing metals that are used in training activities is not uniform throughout the Study Area. Non-explosive munition are the largest portion of expended objects composed of metal or containing metal components (with the exception of target vessels). Approximately 88 percent of the non-explosive munitions and other expended metals used annually during training activities would be used in the Southern California Range Complex, 12 percent in the Hawaii Range Complex. Over 16 million munitions and other items containing metals would be used in the Study Area annually; 99 percent of those munitions and items (by number) are small caliber projectiles. Small caliber projectiles are less than 0.5 in. in diameter and a few inches in length, and weigh up to 0.17 lb.

While the Navy is proposing to conduct three Sinking Exercises per year in the Hawaii Range Complex and one in the Southern California Range Complex, historically, the Navy has not conducted this activity on an annual basis (Table 3.2-11). The last Sinking Exercise conducted in the Pacific was in 2016. A Navy vessel used as a target would weigh between 5,000 and 10,000 tons (aircraft carriers would not be used as a target in Sinking Exercises). The vessel used during the Sinking Exercise would comprise a substantial amount of the metal used in the Study Area by weight, and would also represent the greatest concentration of expended metal objects (including munitions) in any location in the Study Area once the vessel sinks to the seafloor. As noted in previous sections, decommissioned vessels used as targets for sinking exercises have been cleaned or remediated in accordance with USEPA guidelines. Sinking exercises must be conducted at least 50 NM offshore and in water at least 6,000 ft. deep (40 CFR part 229.2). The USEPA considers the contaminant levels associated with the sinking of a target vessel to be within the standards of the Marine Protection, Research, and Sanctuaries Act (16 U.S.C. 1341, et seq.).

Metals from munitions, vessels and other targets, and other expended materials would sink to the seafloor where they would most likely be buried or partially buried in sediments, depending on the type of seafloor substrate. In the areas of the HSTT Study Area where the offshore substrate is predominantly composed of soft sediments (see Section 3.5, Habitats), the likelihood of complete or partial burial of expended materials, including munitions, is greater. Metals exposed to the seawater would slowly corrode over years or decades, releasing small amounts of water soluble metal compounds into the water column and corrosion products into adjacent sediments. The low, near freezing water temperatures and low oxygen levels in sediments only a few inches below the water column-seafloor interface that characterize deepwater (greater than 250 m), benthic habitats would inhibit corrosion of metals and any dispersion of metals and corrosion products beyond isolated areas adjacent to the munition.

As described in Section 3.2.3.3 (Metals), sediment samples collected from World War II era munitions disposal sites and heavily used Navy ranges show that metals are not impacting sediment quality despite longtime use and high concentrations of military munitions composed primarily of metal components. The concentration of munitions and other expended materials containing metals in any one location in the HSTT Study Area would be a small fraction of that found in a munitions disposal site, a target island used for 45 years, or a water range in a river used for almost 100 years. Chemical, physical, or biological changes to sediments or water quality in the Study Area would not be detectable and would be similar to nearby areas without munitions or other expended materials containing metals. This conclusion is based on the following: (1) most of the metals are benign, and those of potential concern make up a small percentage of expended munitions and other metal objects; (2) metals released through corrosion would be diluted by currents or bound up and sequestered in adjacent sediment; (3) elevated concentrations of metals in sediments would be limited to the immediate area around the expended material; and (4) the areas over which munitions and other metal components would be distributed are large.

Based on findings from these and other intensively used locations, the sediment and water quality effects from metals used in munitions, expended materials, target vessels, or other devices resulting from any of the proposed activities would be negligible by comparison and would not adversely affect benthic and water column habitat.

3.2.3.3.1.2 Impacts from Metals Under Alternative 1 for Testing Activities

The distribution of non-explosive munitions and other expended materials composed of or containing metals that are used in testing activities is not uniform throughout the Study Area. Munition are the largest portion of expended objects composed of metal or containing metal components. Approximately 63 percent of the non-explosive munitions and other expended metals used annually during testing activities would be used in the Southern California Range Complex and 46 percent would be used in the Hawaii Range Complex. Over 4 million munitions and other items containing metals would be used in the Study Area annually; 62 percent of those munitions and other items are non-explosive medium caliber projectiles, and 16 percent are small caliber projectiles.

As described in Section 3.2.3.3 (Metals), sediment samples collected from World War II era munitions disposal sites and heavily used Navy ranges show that metals are not impacting sediment quality despite longtime use and high concentrations of military munitions composed primarily of metal components. The concentration of munitions and other expended materials containing metals in any one location in the Study Area would be a small fraction of that from a munitions disposal site, a target island used for 45 years, or a water range in a river used for almost 100 years. Chemical, physical, or biological changes to sediments or water quality in the Study Area would not be detectable and would be similar to nearby areas without munitions or other expended materials containing metals. This conclusion is based on the following: (1) most of the metals are benign, and those of potential concern make up a small percentage of expended munitions and other metal objects; (2) metals released through corrosion would be diluted by currents or bound up and sequestered in adjacent sediment; (3) elevated concentrations of metals in sediments would be limited to the immediate area around the expended material; and (4) the areas over which munitions and other metal components would be distributed are large (thousands of square nautical miles).

Based on findings from these and other intensively used locations, the sediment and water quality effects from metals used in munitions, expended materials, or other devices resulting from any of the proposed activities would be negligible by comparison.

3.2.3.3.2 Impacts from Metals Under Alternative 2

3.2.3.3.2.1 Impacts from Metals Under Alternative 2 for Training Activities

Under Alternative 2, the Navy would conduct 20 Sinking Exercises over five years (compared to just 8 under Alternative 1). Additional increases in the number of training events that would be conducted under Alternative 2 are shown in Table 2.6-1 in Chapter 2 (Description of Proposed Action and Alternatives). As described above, conducting additional sinking exercises would introduce a substantial amount of metals into the marine benthic environment. The sunken vessel would reside on the seafloor at a depth of at least 6,000 ft. where temperatures are constantly near freezing and dissolved oxygen content in water and sediments is low, conditions that slow the corrosion process (refer back to Section 3.2.3.3, Metals), While the potential impact to sediments would be greater than under Alternative 1, metals in the additional vessels would be subject to the same slow degradation rates expected to occur in the deepwater environment limiting any increase in metal concentrations to sediments that are immediately adjacent the sunken vessels (see Section 3.2.3.3, Metals, for additional discussion). As sunken vessels degrade over time on the seafloor, they may become encrusted with oxidation products (e.g., rust) or by marine organisms attracted to hard substrates, which would further slow degradation rates. Based on this analysis, impacts on sediments and water quality may be greater than under Alternative 1, but would still be minimal and would not adversely affect benthic and water column habitat.

3.2.3.3.2.2 Impacts from Metals Under Alternative 2 for Testing Activities

Under Alternative 2, the number of munitions and other expended materials containing metals used during testing activities would increase compared to the number under Alternative 1. As shown in Chapter 2 (Description of Proposed Action and Alternatives) Tables 2.6-2 through 2.6-5, several Navy testing activities would be conducted more often under Alternative 2, resulting in a less than 2 percent increase in the number of explosive and non-explosive munitions and other expended material containing metals.

The increase in the use of munitions and other objects containing metals would increase the amount of metals introduced into the seafloor environment over the amount in Alternative 1. However, the increase is not a substantial increase over the number of munitions used under Alternative 1 and would not alter the conclusions presented for Alternative 1. Specifically, the concentration of munitions and other expended materials containing metals in any one location in the HSTT Study Area would be a small fraction of the concentrations found on a munitions disposal site, a target island used for 45 years, or a water range in a river used for almost 100 years. The increase in the chemical, physical, or biological changes to sediments or water quality in the Study Area would not be detectable. The areas over which the additional 2 percent of munitions and other metal components would be distributed are large (thousands of square nautical miles); therefore any increase would have a negligible effect on metal concentrations in seafloor sediments.

Based on findings from intensively used locations, the sediment and water quality effects from metals used in munitions, expended materials, or other devices resulting from any of the proposed activities would be negligible by comparison and would not adversely affect benthic and water column habitat. Therefore, metals in munitions and other military expended materials are expected to have similar potential environmental impacts as under Alternative 1.

3.2.3.3.3 Impacts from Metals Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Metals would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.2.3.4 Other Materials

Under the Proposed Action, other materials include marine markers and flares, chaff, towed and stationary targets, and miscellaneous components of other expended objects (e.g., concrete blocks used as anchors) (see Appendix F, Military Expended Material and Direct Strike Impact Analyses, for details). These materials and components are either made mainly of non-reactive or slowly reactive materials (e.g., glass, carbon fibers, and plastics) or break down or decompose into benign byproducts (e.g., rubber, steel, iron, and concrete). Most of these objects would settle to the seafloor where they would

(1) be exposed to seawater, (2) become lodged in or covered by seafloor sediments, (3) become encrusted by oxidation products such as rust, (4) dissolve slowly, or (5) be covered by marine organisms such as coral. Plastics may float or descend to the bottom, depending upon their buoyancy. Marine markers and flares are largely consumed during use.

Towed and stationary targets include floating steel drums; towed aerial targets; the trimaran; and inflatable, floating targets. The trimaran is a three-hulled boat with a 4 ft. square sail that is towed as a moving target. Large, inflatable, plastic targets can be towed or left stationary. Towed aerial targets are either (1) rectangular pieces of nylon fabric 7.5 ft. by 40 ft. that reflect radar or lasers; or (2) aluminum cylinders with a fiberglass nose cone, aluminum corner reflectors (fins), and a short plastic tail section. This second target is about 10 ft. long and weighs about 75 lb. These four targets are recovered after use, and will not be considered further.

Marine markers are pyrotechnic devices that are dropped on the water's surface during training exercises to mark a position, to support search and rescue activities, or as a bomb target. The MK 58 marker is a tin tube that weighs about 12 lb. Markers release smoke at the water surface for 40 to 60 minutes. After the pyrotechnics are consumed, the marine marker fills with seawater and sinks. Iron and aluminum constitute 35 percent of the marker by weight. To produce the lengthy smoke effect, approximately 40 percent of the marker by weight is made up of pyrotechnic materials. The propellant, explosive, and pyrotechnic constituents of MK 58 include red phosphorus (2.19 lb.) and manganese (IV) dioxide (1.40 lb.). Other constituents include magnesium powder (0.29 lb.), zinc oxide (0.12 lb.), nitrocellulose (0.000017 lb.), nitroglycerin (0.000014 lb.), and potassium nitrate (0.2 lb.). The failure rate of marine markers is approximately 5 percent (U.S. Department of the Navy, 2010a, 2010d).

Flares are used to signal, to illuminate surface areas at night in search and attack operations, and to assist with search and rescue activities. They range in weight from 5 to 14 kg. The major constituents of flares include magnesium granules and sodium nitrate. Containers are constructed of aluminum, and the entire assembly is usually consumed during flight. Flares may also contain a primer such as trinitrotoluene (TNT), propellant (ammonium perchlorate), and other explosives. These materials are present in small quantities (e.g., 1.0×10^{-4} ounces [oz.] of ammonium perchlorate and 1.0×10^{-7} oz. of explosives). Small amounts of metals are used to give flares and other pyrotechnic materials bright and distinctive colors. Combustion products from flares include magnesium oxide, sodium carbonate, carbon dioxide, and water. Illuminating flares and marine markers are usually entirely consumed during use; neither is intended to be recovered. Table 3.2-14 summarizes the components of markers and flares (U.S. Department of the Air Force, 1997).

Table 3.2-14: Summary of Components of Marine Markers and Flares

Flare or Marker	*Constituents*	*Composition (%)*
LUU-2 Paraflare	Magnesium granules, sodium nitrate, aluminum, iron, trinitrotoluene (TNT), royal demolition explosive, ammonium perchlorate, potassium nitrate, lead, chromium, magnesium, manganese, nickel	Magnesium (54), sodium nitrate (26), aluminum (14), iron (5)
MK45 Paraflare	Aluminum, sodium nitrate, magnesium powder, nitrocellulose, trinitrotoluene (TNT), copper, lead, zinc, chromium, manganese, potassium nitrate, pentaerythritol-tetranitrate, nickel, potassium perchlorate	Magnesium (45), sodium nitrate (30), aluminum (22)
MK58 Marine Marker	Aluminum, chromium, copper, lead, lead dioxide, manganese dioxide, manganese, nitroglycerin, red phosphorus, potassium nitrate, silver, zinc, zinc oxide	Iron (60), aluminum (35)

Most of the pyrotechnic components of marine markers are consumed and byproducts are released into the air. Thereafter, the aluminum and steel canister sinks to the bottom. Combustion of red phosphorus produces phosphorus oxides, which have a low toxicity to aquatic organisms. The amount of flare residue is negligible. Phosphorus contained in the marker settles to the seafloor, where it reacts with the water to produce phosphoric acid until all phosphorus is consumed by the reaction. Phosphoric acid is a variable, but normal, component of seawater (U.S. Department of the Navy, 2006b). The aluminum and iron canisters are expected to be covered by sand and sediment over time, to become encrusted by chemical corrosion, or to be covered by marine plants and animals. Elemental aluminum in seawater tends to be converted by hydrolysis to aluminum hydroxide, which is relatively insoluble, adheres to particulates, and is transported to the bottom sediments (Monterey Bay Research Institute, 2010).

Red phosphorus, the primary pyrotechnic ingredient, constitutes 18 percent of the marine marker by weight. Toxicological studies of red phosphorus revealed an aquatic toxicity in the range of 10–100 mg/L (10–100 ppm) for fish, *Daphnia* (a small aquatic crustacean), and algae (European Flame Retardants Association, 2002). Red phosphorus slowly degrades by chemical reactions to phosphine and phosphorus acids. Phosphine is very reactive and usually undergoes rapid oxidation. The final products, phosphates, are harmless (U.S. Department of the Navy, 2010a, 2010d). A study by the U.S. Department of the Air Force (1997) found that, in salt water, the degradation products of flares that do not function properly include magnesium and barium.

Chaff is an electronic countermeasure designed to confuse enemy radar by deflecting radar waves and thereby obscuring aircraft, ships, and other equipment from radar tracking sources. Chaff consists of small, thin glass fibers coated in aluminum that are light enough to remain in the air anywhere from 10 minutes to 10 hours (Farrell & Siciliano, 2007). Chaff is typically packaged in cylinders that measure approximately 6 in. by 1.5 in. (15.2 cm by 3.8 cm), weigh about 5 oz. (140 grams [g]), and contain a few million fibers. Chaff may be deployed from an aircraft or may be launched from a surface vessel.

The chaff fibers are approximately the thickness of a human hair (generally 25.4 microns in diameter) and range in length from 0.8 to 5.1 cm. The major components of the chaff glass fibers and the aluminum coating are provided in Table 3.2-15 (Arfsten et al., 2002; Farrell & Siciliano, 2007; U.S. Department of the Air Force, 1997; U.S. Department of the Navy, 1999).

Factors influencing chaff dispersion include the altitude and location where it is released, prevailing winds, and meteorological conditions (Spargo, 2007; U.S. Department of the Navy, 1999). Doppler radar has tracked chaff plumes containing approximately 900 g of chaff drifting 200 miles from the point of release, with the plume covering a volume of greater than 400 cubic miles (Arfsten et al., 2002). Based on the dispersion characteristics of chaff, large areas of open water would be exposed to chaff, but the chaff concentrations would be low. For example, U.S. Department of the Navy (1999) calculated that an area 8 km by 12 km (96 square km) would be affected by deployment of a single cartridge containing 150 g of chaff. The resulting chaff concentration would be about 5.4 g per NM^2. This corresponds to less than 0.005 fiber per square meter, assuming that each canister contains 5 million fibers.

Table 3.2-15: Major Components of Chaff

Component	*Percent by Weight*
Glass Fiber	
Silicon dioxide	52–56
Alumina	12–16
Calcium oxide, magnesium oxide	16–25
Boron oxide	8–13
Sodium oxide, potassium oxide	1–4
Iron oxide	≤ 1
Aluminum Coating	
Aluminum	99.45 (min.)
Silicon and Iron	0.55 (max.)
Copper	0.05
Manganese	0.05
Zinc	0.05
Vanadium	0.05
Titanium	0.05
Others	0.05

Chaff is generally resistant to chemical weathering and likely remains in the environment for long periods. However, all the components of chaff's aluminum coating are present in seawater in trace amounts, except magnesium, which is present at 0.1 percent (Nozaki, 1997). Aluminum is the most common metal in the Earth's crust and also occurs naturally in trace amounts in the aquatic environment. Aluminum oxide and silicon dioxide are the two most common minerals in the earth's crust, and ocean waters are constantly exposed to both minerals, so the addition of small amounts of chaff would not affect water quality or sediment composition (U.S. Department of the Navy, 1999).

The dissolved concentration of aluminum in seawater ranges from 1 to 10 µg/L (1 to 10 ppb). For comparison, the concentration in rivers is 50 µg/L (50 ppb). In the ocean, aluminum concentrations tend to be higher on the surface, lower at middle depths, and higher again at the bottom (Li et al., 2008). Aluminum is a very reactive element and is seldom found as a free metal in nature except under highly acidic (low pH) or alkaline (high pH) conditions. It is found combined with other elements, most commonly with oxygen, silicon, and fluorine. These chemical compounds are commonly found in soil, minerals, rocks, and clays (Agency for Toxic Substances and Disease Registry, 2008; U.S. Department of the Air Force, 1994). Elemental aluminum in seawater tends to be converted by hydrolysis to aluminum hydroxide, which is relatively insoluble, and is scavenged by particulates and transported to bottom sediments (Monterey Bay Research Institute, 2010).

Because of their light weight, chaff fibers tend to float on the water surface for a short period. The fibers are quickly dispersed by waves and currents. They may be accidentally or intentionally ingested by marine life, but the fibers are non-toxic. Chemicals leached from the chaff would be diluted by the surrounding seawater, reducing the potential for chemical concentrations to reach levels that can affect sediment quality or benthic habitats.

Schiff (1977) placed chaff samples in Chesapeake Bay water for 13 days. No increases in concentration of greater than 1 ppm of aluminum, cadmium, copper, iron, or zinc were detected. Accumulation and concentration of chaff constituents is not likely under natural conditions. A U.S. Air Force study of chaff analyzed nine elements under various pH conditions: silicon, aluminum, magnesium, boron, copper, manganese, zinc, vanadium, and titanium. Only four elements were detected above the 0.02 mg/L detection limit (0.02 ppm): magnesium, aluminum, zinc, and boron (U.S. Department of the Air Force, 1994). Tests of marine organisms detected no impacts of chaff exposure at levels above those expected in the Study Area (Farrell & Siciliano, 2007).

3.2.3.4.1 Impacts from Other Materials Under Alternative 1

3.2.3.4.1.1 Impacts from Other Materials Under Alternative 1 for Training Activities

The distribution of other expended materials used in training activities would not be uniform throughout the Study Area. These other expended materials include marine markers and flares, chaff, expendable towed and stationary targets, non-explosive sonobuoys, wires and cables, and miscellaneous components. Approximately 70 percent of these other expended items would be used annually in the Southern California portion of the HSTT Study Area and 30 percent in the Hawaii Range Complex. For details on the numbers and types of military expended materials used in the Study Area, refer to Appendix F (Military Expended Material and Direct Strike Impact Analyses) and Section 3.0 (Introduction).

A large portion of these other materials are components of non-explosives sonobuoys (i.e., passive and acoustic sonobuoys), which contain metals and other materials including plastics, and small decelerator/parachutes. Flares and marine markers also make up a substantial portion of these other expended materials. Most pyrotechnics in marine markers and flares are consumed during use, and combustion byproducts are expended into the air before the flare or marine marker contacts the water. The failure rates of flares and marine makers are low (5 percent), and the unconsumed amounts of pyrotechnics that would enter the water are small and subject to additional chemical reactions and subsequent dilution in the ocean. Refer to Appendix F (Military Expended Material and Direct Strike Impact Analyses) and Section 3.0 (Introduction) for the numbers of non-explosive sonobuoys, flares, and marine markers proposed for use under Alternative 1.

As shown in Table 3.2-14, the bulk of the materials used in flares and marine markers are metals and other chemical compounds that occur naturally in the marine environment and would be dispersed at low concentrations in the water column or would sink to the seafloor. The analysis and conclusions presented in Section 3.2.3.3 (Metals) would apply to metals in pyrotechnics as well, and the analysis concludes that sediment and water quality effects from metals would be negligible. The small amounts of explosives used in flares, specifically trinitrotoluene (TNT) and royal demolition explosive, released into the sediments would not impact marine sediments for the same reasons presented in Section 3.2.3.1 (Explosives and Explosives Byproducts). Based on the results of studies conducted at multiple marine and freshwater ranges where explosives have been used intensively over decades, no impacts on sediments and water quality from explosives or pyrotechnics in unconsumed flares and marine markers would be expected.

Plastics and other floating expended materials (e.g., rubber components) would either degrade over time in the water column or on the seafloor or wash ashore. Materials that sink to the seafloor would be widely distributed over the large areas used for training. As described in Section 3.2.2.1.3 (Marine Debris in Nearshore and Offshore Areas off the Hawaiian Islands), the worldwide use and disposal of plastics is rapidly increasing the amount of plastics accumulating in large areas of the world's oceans. Small pieces of plastic associated with the use of chaff, flares, and targets would likely persist in the marine environment as floating debris in the water column or on the seafloor. Plastic floating near the surface and exposed to the sun and mechanical wear and tear would breakdown over time. Plastic that sinks in the water column below the photic zone or to the seafloor would degrade more slowly or not at all. Because only small pieces of plastics would be expended—larger pieces from targets are recovered—and dispersed over a large area, only negligible impacts on sediments or water quality are expected. The potential effects of plastics from military expended materials on living marine resources and habitats are analyzed in other sections of the EIS/OEIS.

Devices temporarily deployed on the seafloor and then recovered following completion of the activity would likely increase turbidity in the vicinity of the device. Most seafloor devices are stationary; however, some devices (e.g., crawlers) are mobile and move very slowly along the bottom. While a minimal increase in turbidity would be expected during installation, recovery, and, if applicable, movement of seafloor devices, particularly where the seafloor is composed of soft sediments, the increase is expected to be negligible and have no lasting impact on sediments or water quality.

3.2.3.4.1.2 Impacts from Other Materials Under Alternative 1 for Testing Activities

The distribution of other expended materials used in testing activities would not be uniform throughout the Study Area. These other expended materials include marine markers and flares, chaff, expendable towed and stationary targets, non-explosive sonobuoys, wires and cables, and miscellaneous components. Approximately 55 percent of these other expended materials would be used annually in the Southern California portion of the HSTT Study Area and 45 percent in the Hawaii Range Complex. For details on the numbers and types of military expended materials used in the Study Area refer to Appendix F (Military Expended Material and Direct Strike Impact Analyses) and Section 3.0 (Introduction).

A large portion of these other materials are components of non-explosives sonobuoys (i.e., passive and acoustic sonobuoys), which contain metals and other materials including plastics, and small decelerator/parachutes. Larger portions of the remaining types of other expended materials are flares, endcaps, pistons, and sabots. A sabot is a device used to keep a projectile centered in the barrel during firing. Sabots are constructed primarily of metal with plastic parts.

Most pyrotechnics in marine markers and flares are consumed during combustion, and byproducts are expended into the air before the flare or marine marker contact the water. The failure rate of flares and marine makers is low (5 percent), and the unconsumed amounts of pyrotechnics that would enter the water are small and subject to additional chemical reactions and subsequent dilution in the ocean. The analysis and conclusions presented in Section 3.2.3.3 (Metals) would apply to metals in pyrotechnics as well, and the analysis concludes that sediment and water quality effects from metals would be negligible. The small amounts of explosives used in flares, specifically trinitrotoluene (TNT) and royal demolition explosive, released into the sediments would not impact marine sediments for the same reasons presented in Section 3.2.3.1 (Explosives and Explosives Byproducts). Based on the results of studies conducted at multiple marine and freshwater ranges where explosives have been used intensively over decades, no impacts on sediments and water quality from explosives or pyrotechnics in unconsumed flares and marine markers would be expected.

Plastics and other floating expended materials (e.g., rubber components) would either degrade over time in the water column or on the seafloor or wash ashore. Materials that sink to the seafloor would be widely distributed over the large areas used for testing. As described in Section 3.2.2.1.3 (Marine Debris in Nearshore and Offshore Areas off the Hawaiian Islands), the worldwide use and disposal of plastics is rapidly increasing the amount of plastic accumulating in large areas of the world's oceans. Small pieces of plastic associated with the use of chaff, flares, and targets would likely persist in the marine environment as floating debris in the water column or on the seafloor. Plastic floating near the surface and exposed to the sun and mechanical wear and tear would breakdown over time. Plastic that sinks in the water column below the photic zone or to the seafloor would degrade more slowly or not at all. Because only small pieces of plastics would be expended—larger pieces from targets are recovered—and dispersed over a large area, only negligible impacts on sediments or water quality are expected. The potential effects of plastics from military expended materials on living marine resources and habitats are analyzed in other sections of the EIS/OEIS. Some testing activities would involve the use of a biodegradable polymer as part of a vessel entanglement system. Based on the constituents of the biodegradable polymer, the Navy anticipated that the material will break down into small pieces within a few days to weeks. The polymer will breakdown further and dissolve into the water column within weeks to a few months. The final breakdown products are all environmentally benign and will be dispersed quickly to undetectable concentrations within the water column.

Devices temporarily deployed on the seafloor and then recovered following completion of the activity would likely increase turbidity in the vicinity of the device. Most seafloor devices are stationary; however some devices (e.g., crawlers) are mobile and move very slowly along the bottom. While a minimal increase in turbidity would be expected during installation, recovery, and, if applicable, movement of seafloor devices, particularly where the seafloor is composed of soft sediments, the increase is expected to be negligible and have no lasting impact on sediments or water quality.

3.2.3.4.2 Impacts from Other Materials Under Alternative 2

3.2.3.4.2.1 Impacts from Other Materials Under Alternative 2 for Training Activities

Under Alternative 2, the number of other expended materials would increase by approximately 8 percent. The additional expended materials are non-explosive sonobuoys and their small decelerator/parachutes. The small increase in plastics and metals in the additional expended materials would not change the conclusions presented under Alternative 1. Therefore, impacts from other materials would be expected to be approximately the same as those analyzed under Alternative 1.

3.2.3.4.2.2 Impacts from Other Materials Under Alternative 2 for Testing Activities

Under Alternative 2, the number of other expended materials would increase by approximately 4 percent. The additional expended materials are non-explosive sonobuoys and their small decelerator/parachutes. The small increase in plastics and metals in the additional expended materials would not change the conclusions presented under Alternative 1. Therefore, impacts from other materials would be expected to be approximately the same as those analyzed under Alternative 1.

3.2.3.4.3 Impacts from Other Materials Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Other materials would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.2.4 Summary of Potential Impacts on Sediments and Water Quality

The stressors that may impact sediments and water quality include explosives and explosives byproducts, metals, chemicals other than explosives, and other materials. As described in Section 3.0.3.5 (Resource-Specific Impacts Analysis for Multiple Stressors), this section evaluates the potential for combined impacts of all the stressors on sediments and water quality. The analysis and conclusions for the potential impacts from each of the individual stressors are discussed in the sections above. Stressors associated with Navy training and testing activities do not typically occur in isolation but rather occur in some combination. For example, some anti-submarine warfare activities use explosive sonobuoys, which may introduce residual explosives, explosives byproducts, metals, and plastic materials into the environment during a single activity. An analysis of the combined impacts of all stressors on sediments and water quality considers the potential consequences of aggregate exposure to all stressors and the repetitive or additive consequences of exposure over multiple years.

3.2.4.1 Combined Impact of All Stressors Under Alternative 1

Most Navy training and testing activities impact small, widely dispersed areas of the Study Area, limiting the spatial extent of sediments and the water column that would be exposed to contaminants to isolated areas within the Study Area. However, some Navy activities recur in the same location (e.g., gunnery and mine warfare activities), which concentrates munitions and other materials and their associated stressors in those areas. Despite recent, comprehensive data collection and analysis specific to military munitions impacts on sediments and water quality (Briggs et al., 2016; Edwards & Bełdowski, 2016; Edwards et al., 2016a; Edwards et al., 2016b; Tomlinson & De Carlo, 2016), analysis of the potential effects from the Proposed Action is mainly speculative. Where combinations of explosives, explosives byproducts, metals, and other chemicals and materials are co-located, the potential for combined impacts is present (Thompson et al., 2009).

When considered together, the impact of the four stressors would be additive. Under Alternative 1, chemical, physical, or biological changes in sediments and water quality would be minimal and only detectable in the immediate vicinity of munitions. Even in areas were multiple munitions and expended materials are located in close proximity (e.g., munitions disposal sites) chemical degradation products from each source or item are largely isolated from each other. The low failure rate of explosive munitions proposed for use reduces the likelihood of exposure to explosives materials that remain in intact munitions. Measurable concentrations of contaminants and other chemicals in the marine environment from munitions disposal sites have been shown to be below screening levels or similar to nearby reference areas where munitions are not present. Many components of non-explosive munitions and other expended materials are inert or corrode slowly over years. Metals that could impact benthic habitat at higher concentrations comprise only a small portion of the alloys used in expended materials, and corrosion of metals in munitions casings and other expended materials is a slow process that allows for dilution. The chemicals products from hydrolysis are predominantly naturally occurring chemicals. Elevated concentrations of metals and other chemical constituents in sediments would be limited to small zones adjacent to the munitions or other expended materials and would still most likely remain below screening levels even after years residing on the seafloor. It is also possible that Navy stressors will combine with non-Navy stressors, particularly in nearshore areas and bays, such as Pearl Harbor and San Diego Bay, to exacerbate already impacted sediments and water quality. This is qualitatively discussed in Chapter 4 (Cumulative Impacts).

3.2.4.2 Combined Impact of All Stressors Under Alternative 2

Under Alternative 2, when considered separately, the impact of the four stressors on sediments and water quality would be approximately the same as discussed under Alternative 1, because the types of explosives, chemicals other than explosives, metals, and military expended materials are approximately equivalent under the two alternatives.

The amounts of explosives are greater under Alternative 2, because of the increase in the number of sinking exercises and some testing activities that would be conducted under Alternative 2. While the potential impact to sediments would be slightly greater than under Alternative 1, metals in the additional vessels and munitions would be subject to the same slow degradation rates expected to occur in the deepwater environment limiting any increase in metal concentrations to sediments that are immediately adjacent the sunken vessels (see Section 3.2.3.3, Metals, for additional discussion). As sunken vessels degrade over time on the seafloor, they may become encrusted with oxidation products (e.g., rust) or by marine organisms attracted to hard substrates, which would further slow degradation rates. As discussed in Section 3.2.3.1 (Explosives and Explosives Byproducts), degrading munitions at World War II-era munitions disposal sites do not pose a risk to human health or to the fauna living in direct contact with the degrading munitions (Edwards & Bełdowski, 2016; Edwards et al., 2016b). During a comprehensive survey of a disposal site off of Hawaii, explosive materials were detected in sediments at only two locations and the concentrations were low. Data supporting these conclusions were collected from several World War II era munitions disposal sites and ranges characterized by relatively high concentrations of munitions. Munitions used in the proposed training and testing activities would be widely dispersed by comparison, resulting in lower concentrations of munitions that failed to detonate and lower concentrations of residual explosives and explosives byproducts than reported in Edwards et al. (2016b).

Based on this analysis, impacts on sediments and water quality may be slightly greater than under Alternative 1, but would still be minimal. Therefore, combined impacts from all stressors would also be similar to impacts described under Alternative 1.

3.2.4.3 Combined Impact of All Stressors Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. The stressors potentially impacting sediments and water quality (e.g., explosives, explosive byproducts, metals) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

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REFERENCES

Agency for Toxic Substances and Disease Registry. (1999). *Toxicological Profile for Mercury*. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Agency for Toxic Substances and Disease Registry. (2005). *Public Health Assessment for Pearl Harbor Naval Complex*. (EPA Facility ID: HI4170090076). Pearl Harbor, HI: Department of Health and Human Services.

Agency for Toxic Substances and Disease Registry. (2007). *Toxicological Profile for Lead*. Atlanta, GA: U.S. Department of Health and Human Services.

Agency for Toxic Substances and Disease Registry. (2008). *Toxicological Profile for Perchlorates*. Atlanta, GA: U.S. Department of Health and Human Services.

Andrady, A. (2015). Persistence of plastic litter in the oceans. In M. Bergmann, L. Gutow, & M. Klages (Eds.), *Marine Anthropogenic Litter*. New York, NY: Springer International Publishing.

Ankley, G. T. (1996). Evaluation of metal/acid-volatile sulfide relationships in the prediction of metal bioaccumulation by benthic macroinvertebrates. *Environmental Toxicology and Chemistry, 15*, 2138–2146.

Arfsten, D. P., C. L. Wilson, and B. J. Spargo. (2002). Radio frequency chaff: The effects of its use in training on the environment. *Ecotoxicology and Environmental Safety, 53*, 1–11.

Bergmann, M., L. Gutow, and M. Klages. (2015). *Marine Anthropogenic Litter*. New York, NY and London, United Kingdom: Springer.

Bergmuller, R., R. A. Johnstone, A. F. Russell, and R. Bshary. (2007). Integrating cooperative breeding into theoretical concepts of cooperation. *Behavioural Processes, 2*, 67–72.

Biggs, T. W., and H. D'Anna. (2012). Rapid increase in copper concentrations in a new marina, San Diego Bay. *Marine pollution bulletin, 64*(3), 627–635.

Blott, S. J., and K. Pye. (2012). Particle size scales and classification of sediment types based on particle size distributions: Review and recommended procedures. *Sedimentology, 59*(7), 2071–2096.

Boudreau, B. P. (1998). Mean mixed depth of sediments: The wherefore and the why. *Limnology and Oceanography, 43*(3), 524–526.

Breitbarth, E., E. P. Achterberg, M. V. Ardelan, A. R. Baker, E. Bucciarelli, F. Chever, P. L. Croot, S. Duggen, M. Gledhill, M. Hassellov, C. Hassler, L. J. Hoffmann, K. A. Hunter, D. A. Hutchins, J. Ingri, T. Jickells, M. C. Lohan, M. C. Nielsdottir, G. S. Sarthou, V., J. M. Trapp, D. R. Turner, and Y. Ye. (2010). Iron biogeochemistry across marine systems—progress from the past decade. *Biogeosciences, 7*, 1075–1097.

Briggs, C., S. M. Shjegstad, J. A. K. Silva, and M. H. Edwards. (2016). Distribution of chemical warfare agent, energetics, and metals in sediments at a deep-water discarded military munitions site. *Deep Sea Research Part II: Topical Studies in Oceanography, 128*, 63–69.

Bruland, K. W. (1992). Complexation of cadmium by natural organic ligands in the Central North Pacific. *ASLO Limnology and Oceanography, 37*(5), 1008–1017.

Buchman, M. (2008). *National Oceanic and Atmospheric Administration Screening Quick Reference Tables, National Oceanic and Atmospheric Administration OR&R Report 08-1*. Seattle, WA: Office of Response and Restoration Division National Oceanic and Atmospheric Administration

Byrne, R. H. (1996). Specific problems in the measurement and intrepretation of complexation phenomena in seawater. *Pure and Applied Chemistry, 68*(8), 1639–1656.

Carmody, D. J., J. B. Pearce, and W. E. Yasso. (1973). Trace metals in sediments of New York Bight. *Marine Pollution Bulletin, 4*, 132–135.

Carr, R. S., and M. Nipper. (2003). *Assessment of Environmental Effects of Ordnance Compounds and their Transformation Products in Coastal Ecosystems*. Port Hueneme, CA: Naval Facilities Engineering Service Center.

Carr, S. H., F. Tatman, and F. A. Chapman. (1996). Observations on the natural history of the Gulf of Mexico sturgeon (*Acipenser oxyrinchus de sotoi* Vladykov 1955) in the Suwannee River, southeastern United States. *Ecology of Freshwater Fish, 5*, 169–174.

Center for Ocean Solutions. (2009). *Pacific Ocean Synthesis: Scientific Literature Review of Coastal and Ocean Threats, Impacts, and Solutions*. San Jose, CA: Stanford University.

Chang, M. (2015). Reducing microplastics from facial exfoliating cleansers in wastewater through treatment versus consumer product decisions. *Marine Pollution Bulletin, 101*, 330–333.

Chapman, P. M., F. Wang, C. R. Janssen, R. R. Goulet, and C. N. Kamunde. (2003). Conducting ecological risk assessments of inorganic metals and metalloids: Current status. *Human and Ecological Risk Assessment, 9*(4), 641–697.

Chaturvedi, S., and P. N. Dave. (2015). Solid propellants: AP/HTPB composite propellants. *Arabian Journal of Chemistry, web*.

Chester, R. (2003). *Marine Geochemistry* (2nd ed.). Malden, MA: Blackwell Publishing Company.

Cole, M., and T. S. Galloway. (2015). Ingestion of nanoplastics and microplastics by Pacific oyster larvae. *Environmental Science & Technology, 49*(24), 14625–14632.

Coleman, J. M., and D. B. Prior. (1988). Mass wasting on continental margins. *Annual Review of Earth Planet Science, 16*, 101–119.

Crocker, F. H., K. J. Indest, and H. L. Fredrickson. (2006). Biodegradation of the cyclic nitramine explosives RDX, HMX, and CL-20. *Applied Microbiology and Biotechnology, 73*, 274–290.

Cruz-Uribe, O., D. P. Cheney, and G. L. Rorrer. (2007). Comparison of TNT removal from seawater by three marine macroalgae. *Chemsphere, 67*, 1469–1476.

Currie, J. J., S. H. Stack, J. A. McCordic, and G. D. Kaufman. (2017). Quantifying the risk that marine debris poses to cetaceans in coastal waters of the 4-island region of Maui. *Marine Pollution Bulletin, 121*(1–2), 69–77.

Demina, L. L., and S. V. Galkin. (2009). Geochemical features of heavy metal bioaccumulation in the Guaymas Basin of the Gulf of California. *Oceanology, 49*(5), 697–706.

Dodder, N., K. Schiff, A. Latker, and C. L. Tang (2016). *Southern California Bight 2013 Regional Monitoring Program: Volume IV. Sediment Chemistry* (Technical Report 922). Costa Mesa, CA: Southern California Coastal Water Research Project Authority.

Doi, Y., Y. Kanesawa, N. Tanahashi, and Y. Kumagai. (1992). Biodegradation of microbial polyesters in the marine environment. *Polymer Degradation and Stability, 36*, 173–177.

Edwards, K. P., J. A. Hare, F. E. Werner, and B. O. Blanton. (2006). Lagrangian circulation on the Southeast U.S. Continental Shelf: Implications for larval dispersal and retention. *Continental Shelf Research, 26*(12–13), 1375–1394.

Edwards, M., and J. Bełdowski. (2016). Chemical munitions dumped at sea. *Deep Sea Research Part II: Topical Studies in Oceanography, 128*, 1–3.

Edwards, M. H., D. J. Fornari, M. R. Rognstad, C. D. Kelley, C. L. Mah, L. K. Davis, K. R. M. Flores, E. L. Main, and N. L. Bruso. (2016a). Time-lapse camera studies of sea-disposed chemical munitions in Hawaii. *Deep-Sea Research II: Topical Studies in Oceanography, 128*, 25–33.

Edwards, M. H., S. M. Shjegstad, R. Wilkens, J. C. King, G. Carton, D. Bala, B. Bingham, M. C. Bissonnette, C. Briggs, N. S. Bruso, R. Camilli, M. Cremer, R. B. Davis, E. H. DeCarlo, C. DuVal, D. J. Fornari, I. Kaneakua-Pia, C. D. Kelley, S. Koide, C. L. Mah, T. Kerby, G. J. Kurras, M. R. Rognstad, L. Sheild, J. Silva, B. Wellington, and M. V. Woerkom. (2016b). The Hawaii undersea military munitions assessment. *Deep Sea Research Part II: Topical Studies in Oceanography, 128*, 4–13.

Eggleton, J., and K. V. Thomas. (2004). A review of factors affecting the release and bioavailability of contaminants during sediment disturbance events. *Environment International, 30*(7), 973–980.

Environmental Sciences Group. (2005). *Canadian Forces Maritime Experimental and Test Ranges: Environmental Assessment Update 2005*. Kingston, Canada: Environmental Sciences Group, Royal Military College.

Espinoza, M., and I. S. Wehrtmann. (2008). Stomach content analyses of the threadfin anglerfish *Lophiodes spilurus* (Lophiiformes: Lophiidae) associated with deepwater shrimp fisheries from the central Pacific of Costa Rica. *Revista de Biología Tropical, 56*(4), 1959–1970.

European Flame Retardants Association. (2002). *Flame retardant fact sheet: Red phosphorus*. Retrieved from http://www.cefic-efra.com/Objects/2/Files/RedPhosphorusFactSheet.pdf.

Farrell, R. E., and S. D. Siciliano. (2007). *Environmental Effects of Radio Frequency Chaff Released During Military Training Exercises: A Review of the Literature*. Saskatoon, Canada: Goose Bay Office of the Department of National Defense.

Fitzgerald, W. F., C. H. Lamborg, and C. R. Hammerschmidt. (2007). Marine biogeochemical cycling of mercury. *Chemical Reviews, 107*, 641–662.

Fitzpatrick, J. L., J. K. Desjardins, K. A. Stiver, R. Montgomerie, and S. Balshine. (2006). Male reproductive suppression in the cooperatively breeding fish *Neolamprologus pulcher*. *Behavioural Ecology, 17*, 25–33.

Hameedi, M., A. Pait, and R. Warner. (2002). *Environmental Contaminant Monitoring in the Gulf of Maine*. Paper presented at the Northeast Coastal Monitoring Summit. Durham, NH.

Haugland, M., J. C. Holst, M. Holm, and L. P. Hansen. (2006). Feeding of Atlantic salmon (*Salmo salar* L.) post-smolts in the Northeast Atlantic. *ICES Journal of Marine Science, 63*, 1488–1500.

Hawaii Department of Health. (2014). *2014 State of Hawaii Water Quality Monitoring and Assessment Report* (Integrated Report to the U.S. Environmental Protection Agency and the U.S. Congress Pursuant to §303(d) and §305(b), Clean Water Act [P.L. 97-117]). Honolulu, HI: Clean Water Branch.

Hawaii State Department of Health. (2000). *Hawaii's Implementation Plan for Polluted Runoff Control, Appendix F: Detailed Descriptions of Hawaii's 18 Water Quality Limited Segments*. Honolulu, HI: Hawaii Department of Business and Department of Health.

Hedges, J. I., and J. M. Oades. (1997). Review Paper: Comparative organic geochemistries of soils and marine sediments. *Organic Geochemistry, 27*(7–8), 319–361.

Ho, T.-Y., L.-S. Wen, C.-F. You, and D.-C. Lee. (2007). The trace metal composition of size-fractionated plankton in the South China Sea: Biotic versus abiotic sources. *Limnology and Oceanography, 52*(5), 1776–1788.

Juhasz, A. L., and R. Naidu. (2007). Explosives: Fate, dynamics, and ecological impact in terrestrial and marine environments. *Reviews of Environmental Contamination and Toxicology, 191*, 163–215.

Keller, A. A., E. L. Fruh, M. M. Johnson, V. Simon, and C. McGourty. (2010). Distribution and abundance of anthropogenic marine debris along the shelf and slope of the U.S. West Coast. *Marine Pollution Bulletin, 60*(5), 692–700.

Kelley, C., G. Carton, M. Tomlinson, and A. Gleason. (2016). Analysis of towed camera images to determine the effects of disposed mustard-filled bombs on the deep water benthic community off south Oahu. *Deep Sea Research Part II: Topical Studies in Oceanography, 128*, 34–42.

Kennett, J. P. (1982). *Marine Geology*. New York, NY: Prentice-Hall.

Koide, S., J. A. K. Silva, V. Dupra, and M. Edwards. (2016). Bioaccumulation of chemical warfare agents, energetic materials, and metals in deep-sea shrimp from discarded military munitions sites off Pearl Harbor. *Deep Sea Research Part II: Topical Studies in Oceanography, 128*, 53–62.

Kszos, L. A., J. J. Beauchamp, and A. J. Stewart. (2003). Toxicity of lithium to three freshwater organisms and the antagonistic effect of sodium. *Ecotoxicology, 12*(5), 427–437.

Law, K. L., S. Moret-Ferguson, N. A. Maximenko, G. Proskurowski, E. E. Peacock, J. Hafner, and C. M. Reddy. (2010). Plastic accumulation in the North Atlantic Subtropical Gyre. *Sciencexpress, 329*, 1–8.

Law, K. L., S. E. Moret-Ferguson, D. S. Goodwin, E. R. Zettler, E. Deforce, T. Kukulka, and G. Proskurowski. (2014). Distribution of surface plastic debris in the eastern Pacific Ocean from an 11-year data set. *Environmental Science & Technology, 48*(9), 4732–4738.

Law, K. L., and R. C. Thompson. (2014). Microplastics in the Sea. *Science, 345*(6193), 144–145.

Li, J., J. Ren, J. Zhang, and S. Liu. (2008). The distribution of dissolved aluminum in the Yellow and East China Seas. *Journal of Ocean University of China, 7*(1), 48–54.

Libes, S. M. (2009). *Introduction to Marine Biogeochemistry* (2nd ed.). Burlington, MA, San Diego, CA, and London, United Kingdom: Academic Press.

Long, E. R., D. D. MacDonald, S. L. Smith, and F. D. Calder. (1995). Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Environmental Management, 19*(1), 81–97.

MacDonald, J., and C. Mendez. (2005). *Unexploded Ordnance Cleanup Costs: Implications of Alternative Protocols* (MG-244-RC). Santa Monica, CA, Arlington, VA, and Pittsburgh, PA: RAND Corporation.

Mann, K. H., and J. R. N. Lazier. (1996). *Dynamics of Marine Ecosystems: Biological-Physical Interactions in the Oceans* (2nd ed.). Boston, MA: Blackwell Scientific Publications.

Mato, Y., T. Isobe, H. Takada, H. Kanehiro, C. Ohtake, and T. Kaminuma. (2001). Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. *Environmental Science Technology, 35*, 318–324.

Melillo, J. M., T. Richmond, and G. W. Yohe. (2014). *Climate Change Impacts in the United States: The Third National Climate Assessment*. Washington, DC: U.S. Global Change Research Program.

Missile Technology Control Regime. (1996). *Missile Technology Control Regime*. Retrieved from http://mtcr.info.

Mitchell, C. P. J., and C. C. Gilmour. (2008). Methylmercury production in a Chesapeake Bay salt marsh. *Journal of Geophysical Research, 113*(G2), G00C04.

Mitsch, W. J., and J. G. Gosselink. (2007). *Wetlands* (Fourth ed.). Hoboken, NJ: John Wiley & Sons, Inc.

Mitsch, W. J., J. G. Gosselink, C. J. Anderson, and L. Zhang. (2009). *Wetland Ecosystems*. Hoboken, NJ: John Wiley & Sons, Inc.

Monterey Bay Research Institute. (2010). *Periodic Table of Elements in the Ocean*. *The MBARI Chemical Sensor Program.* Retrieved from www.mbari.org/chemsensor/pteo.htm.

Moore, S., M. Sutula, T. Von Bitner, G. Lattin, and K. Schiff. (2016). *Southern California Bight 2013 Regional Monitoring Program: Volume III. Trash and Marine Debris*. (Technical Report 928). Costa Mesa, CA: Southern California Coastal Water Research Project.

Morel, F. M. M., and N. M. Price. (2003). The biogeochemical cycles of trace metals in the oceans. *Science, 300*(5621), 944–947.

Napper, I. E., A. Bakir, S. J. Rowland, and R. C. Thompson. (2015). Characterisation, quantity and sorptive properties of microplastics extracted from cosmetics. *Marine Pollution Bulletin, 99*(1–2), 178–185.

National Oceanic and Atmospheric Administration. (1999). *Sediment Quality Guidelines Developed for the National Status and Trends Program*. Silver Spring, MD: National Oceanic and Atmospheric Administration.

Neira, C., F. Delgadillo-Hinojosa, A. Zirino, G. Mendoza, L. A. Levin, M. Porrachia, and D. D. Deheyn. (2009). Spatial distribution of copper in relation to recreational boating in a California shallow-water basin. *Chemistry and Ecology, 25*(6), 417–433.

Nipper, M., R. S. Carr, J. M. Biedenbach, R. L. Hooten, and K. Miller. (2002). Toxicological and chemical assessment of ordnance compounds in marine sediments and porewaters. *Marine Pollution Bulletin, 44*, 789–806.

Nozaki, Y. (1997). *Supplementary Materials to "A Fresh Look at Element Distribution in the North Pacific"*. Retrieved from http://www.agu.org/pubs/eos-news/supplements/1995-2003/97026e.shtml.

Pait, A. S., A. L. Mason, D. R. Whitall, J. D. Christensen, and S. I. Hartwell. (2010). Chapter 5: Assessment of Chemical Contaminants in Sediments and Corals in Vieques. In L. J. Bauer & M. S. Kendall (Eds.), *An Ecological Characterization of the Marine Resources of Vieques, Puerto Rico* (pp. 101–150). Silver Spring, MD: National Oceanic and Atmospheric Administration.

Pavlostathis, S. G., and G. H. Jackson. (2002). Biotransformation of 2, 4, 6-trinitrotoluene in a continuous-flow *Anabaena* sp. system. *Water Research, 36*, 1699–1706.

Pennington, J. C., and J. M. Brannon. (2002). Environmental fate of explosives. *Thermochimica Acta, 384*(1–2), 163–172.

Powell, S., P. D. Franzmann, R. Cord-Ruwisch, and S. Toze. (1998). Degradation of 2-nitrodiphenylamine, a component of Otto Fuel II, by *Clostridium* spp. *Anaerobe, 4*, 95–102.

Rabalais, N. N., R. E. Turner, and W. J. Wiseman, Jr. (2002). Gulf of Mexico hypoxia, a.k.a. "The Dead Zone" *Annual Review of Ecology and Systematics, 33*, 235–263.

Schiff, S. C. (1977). *Effects of Aluminized Fiberglass on Representative Chesapeake Bay Marine Organisms*. Washington, DC: U.S. Department of the Navy, Naval Research Laboratory.

Shah, A. A., F. Hasan, A. Hameed, and S. Ahmed. (2008). Biological degradation of plastics: A comprehensive review. *Biotechnology Advances, 26*(3), 246–265.

Sheavly, S. B. (2007). *National Marine Debris Monitoring Program: Final Program Report, Data Analysis, and Summary*. Washington, DC: Ocean Conservancy.

Singh, R., P. Soni, P. Kumar, S. Purohit, and A. Singh. (2009). Biodegradation of high explosive production effluent containing RDX and HMX by denitrifying bacteria. *World Journal of Microbiology and Biotechnology, 25*, 269–275.

Smith, S. H., and D. E. Marx, Jr. (2016). De-facto marine protection from a Navy bombing range: Farallon de Medinilla, Mariana Archipelago, 1997 to 2012. *Marine Pollution Bulletin, 102*(1), 187–198.

Spargo, B. J. (2007). [Personal Communication with Mark Collins Regarding Chaff End Cap and Piston Bouyancy].

State of California. (2009). *California Ocean Plan: Water Quality Control Plan for the Ocean Water of California*. Sacramento, CA: California Environmental Protection Agency.

Stillman, J. H., and A. W. Paganini. (2015). Biochemical adaptation to ocean acidification. *The Journal of Experimental Biology, 218*(Pt 12), 1946–1955.

Svejkovsky, J., N. P. Nezlin, N. M. Mustain, and J. B. Kum. (2010). Tracking stormwater discharge plumes and water quality of the Tijana River with multispectral aerial imagery. *Estuarine, Coastal and Shelf Science, 87*(3), 387–398.

Teuten, E. L., S. J. Rowland, T. S. Galloway, and R. C. Thompson. (2007). Potential for plastics to transport hydrophobic contaminants. *Environmental Science and Technology, 41*(22), 7759–7764.

Thompson, B., A. R. Melwani, and J. A. Hunt. (2009). *Estimated Sediment Contaminant Concentrations Associated with Biological Impacts at San Diego Bay Clean-up Sites*. (SWRCB Agreement No. 08-194-190 Contribution No. 584). Oakland, CA: Aquatic Science Center.

Thompson, S. A., W. J. Sydeman, J. A. Santora, B. A. Black, R. M. Suryan, J. Calambokidis, W. T. Peterson, and S. J. Bograd. (2012). Linking predators to seasonality of upwelling: Using food web indicators and path analysis to infer trophic connections. *Progress in Oceanography, 101*(1), 106–120.

Titmus, A. J., and K. D. Hyrenbach. (2011). Habitat associations of floating debris and marine birds in the North East Pacific Ocean at coarse and meso spatial scales. *Marine Pollution Bulletin, 62*(11), 2496–2506.

Tomlinson, M. S., and E. H. De Carlo. (2016). Occurrence and possible sources of arsenic in seafloor sediments surrounding sea-disposed munitions and chemical agents near Oahu, Hawaii. *Deep Sea Research Part II: Topical Studies in Oceanography, 128*, 70–84.

Turner, R. E., and N. N. Rabalais. (2003). Linking landscape and water quality in the Mississippi River basin for 200 years. *BioScience, 53*(6), 563–572.

U.S. Army Corps of Engineers. (2002). *Silver Strand Shoreline Final General Reevaluation Report*. Imperial Beach, CA: U.S. Army Corps of Engineers.

U.S. Army Corps of Engineers. (2012). *U.S. Waterway Data*. Retrieved from http://www.ndc.iwr.usace.army.mil/data/datawcus.htm.

U.S. Commission on Ocean Policy. (2004). *An Ocean Blueprint for the 21st Century (Final Report)*. Washington, DC: U.S. Commission on Ocean Policy.

U.S. Department of Agriculture. (1993). Soil Survey Manual. In Soil Conservation Service (Ed.), *U.S. Department of Agriculture Handbook 18* (3rd ed.). Washington, DC: U.S. Department of Agriculture.

U.S. Department of the Air Force. (1994). *Technical Reports on Chaff and Flares-Technical Report No. 5: Laboratory Analysis of Chaff and Flare Materials*. Langley Air Force Base, VA: U.S. Air Force Headquarters Air Combat Command.

U.S. Department of the Air Force. (1997). *Environmental Effects of Self-Protection Chaff and Flares*. Langley Air Force Base, VA: U.S. Air Force, Headquarters Air Combat Command.

U.S. Department of the Navy. (1993). *Report on Continuing Action: Standard Range Sonobuoy Quality Assurance Program, San Clemente Island, California*. San Diego, CA: Naval Facilities Engineering Command, Pacific.

U.S. Department of the Navy. (1999). *Environmental Effects of RF Chaff: A Select Panel Report to the Undersecretary of Defense for Environmental Security*. Washington, DC: U.S. Department of the Navy, Naval Research Laboratory.

U.S. Department of the Navy. (2000). *Quantifying in situ Metal Contaminant Mobility in Marine Sediments*. San Diego, CA: Space and Naval Warfare Systems Command.

U.S. Department of the Navy. (2006a). *Final environmental assessment, San Clemente Island wastewater treatment plant: Increase in maximum allowable discharge volume*. San Diego, CA: Naval Facilities Engineering Command Southwest.

U.S. Department of the Navy. (2006b). *2006 Supplement to the 2002 Rim of the Pacific (RIMPAC) Programmatic Environmental Assessment (PEA)*. Washington, DC: U.S. Department of the Navy.

U.S. Department of the Navy. (2008a). *Southern California Range Complex Environmental Impact Statement/Overseas Environmental Impact Statement*. San Diego, CA: Naval Facilities Engineering Command Southwest.

U.S. Department of the Navy. (2008b). *Final Atlantic Fleet Active Sonar Training Environmental Impact Statement/Overseas Environmental Impact Statement*. Norfolk, VA: Naval Facilities Engineering Command, Atlantic.

U.S. Department of the Navy. (2010a). *Water Range Assessment for the Jacksonville Range Complex*. Norfolk, VA: Parsons.

U.S. Department of the Navy. (2010b). *Remedial Investigation Addendum, Pearl Harbor Sediment (Draft Final)*. Pearl Harbor, HI: Naval Facilities Engineering Command, Pacific.

U.S. Department of the Navy. (2010c). *San Clemente Island Range Assessment (Poster).* Paper presented at the 2010 Strategic Environmental Research and Development Program (SERDP) conference.

U.S. Department of the Navy. (2010d). *Water Range Assessment for the VACAPES Range Complex (Final Report)*. Norfolk, VA: Naval Facilities Engineering Command, Atlantic Division.

U.S. Department of the Navy. (2013a). *San Diego Bay Integrated Natural Resources Management Plan*. San Diego, CA: Unified Port of San Diego.

U.S. Department of the Navy. (2013b). *Comprehensive Exercise and Marine Species Monitoring Report For the U.S. Navy's Atlantic Fleet Active Sonar Training (AFAST) and Virginia Capes, Cherry Point, Jacksonville, and Gulf of Mexico Range Complexes 2009–2012*. Norfolk, VA: United States Fleet Forces Command.

U.S. Department of the Navy. (2013c). *Water Range Sustainability Environmental Program Assessment: Potomac River Test Range*. Dahlgren, VA: Naval Surface Warfare Center.

U.S. Department of the Navy. (2013d). *Comprehensive Exercise and Marine Species Monitoring Report for the U.S. Navy's Southern California Range Complex*. San Diego, CA: U.S. Navy Pacific Fleet.

U.S. Environmental Protection Agency. (2008a). *Interim Drinking Water Health Advisory For Perchlorate*. Washington, DC: Health and Ecological Criteria Division.

U.S. Environmental Protection Agency. (2008b). *Toxicity Characteristic Leaching Procedure (TCLP) for VOCs, SVOCs, Chlorinated Pesticides and Herbicides, and Metals by SW-846 Method 1311 and Analysis*. Washington, DC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. (2009). *National Recommended Water Quality Criteria*. Washington, DC: Office of Water and the Office of Science and Technology. Retrieved from http://www.epa.gov/ost/criteria/wqctable/.

U.S. Environmental Protection Agency. (2010). *National Marine Debris Monitoring Program: Lessons Learned*. Virginia Beach, VA: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. (2012a). *National Coastal Condition Report IV*. Washington, DC: Office of Research and Development/Office of Water. Retrieved from http://water.epa.gov/type/oceb/assessmonitor/nccr/index.cfm.

U.S. Environmental Protection Agency. (2012b). *EPA Federal Facilities Forum Fact Sheet*. (Environmental Protection Agency/505/S-11/001). Washington, DC: Solid Waste and Emergency Response.

U.S. Environmental Protection Agency. (2014). *2014 Letter: Marine Protection, Research, and Sanctuaries Act (MPRSA) General Permit for the Sinking Exercise (SINKEX) Program; Evaluation, Determination, and Agreement*. Washington, DC: U.S. Department of the Navy.

U.S. Environmental Protection Agency. (2016). *National Coastal Condition Assessment 2010*. (Environmental Protection Agency 841-R-15-006). Washington, DC: Office of Water and Office of Research and Development. Retrieved from http://www.epa.gov/national-aquatic-resource-surveys/ncca.

University of Hawaii. (2010). *Hawaii Undersea Military Munitions Assessment, Final Investigation Report HI-05, South of Pearl Harbor, Oahu, HI*. Honolulu, HI: University of Hawaii at Manoa.

Valette-Silver, N. J. (1993). The use of sediment cores to reconstruct historical trends in contamination of estuarine and coastal sediments. *Estuaries, 16*(3, Part B: Dedicated Issue: Historical Trends in Contamination of Estuarine and Coastal Sediments: Symposium Papers from the Eleventh Biennial International Estuarine Research Conference), 577–588.

Venrick, E. L., T. W. Backman, W. C. Bartram, C. J. Platt, M. S. Thornhill, and R. E. Yates. (1973). Man-made objects on the surface of the central North Pacific Ocean. *Nature, 241*(5387), 271–271.

Walker, S. W., C. L. Osburn, T. J. Boyd, L. J. Hamdan, R. B. Coffin, M. T. Montgomery, J. P. Smith, Q. X. Li, C. Hennessee, F. Monteil, and J. Hawari. (2006). *Mineralization of 2, 4, 6-Trinitrotoluene (TNT) in Coastal Waters and Sediments*. Washington, DC: U.S. Department of the Navy, Naval Research Laboratory.

Wallace, G. T., Jr., G. L. Hoffman, and R. A. Duce. (1977). The influence of organic matter and atmospheric deposition on the particulate trace metal concentration of northwest Atlantic surface seawater. *Marine Chemistry, 5*, 143–170.

Wang, P., K. Richer, L. Rivera-Duarte, B. Davidson, B. Wild, R. Baru, Q. Liao, J. Germano, K. Markille, and J. Gailari. (2014a). *Evaluation of Resuspension from Propeller Wash in Pearl Harbor and San Diego Bay*. (Technical Report 2036). San Diego, CA: Space and Naval Warfare Systems Center Pacific.

Wang, P. F., D. Sutton, K. Richter, and B. Chadwick. (2000). *Modeling Migration of Sediment and Sorbed Contaminants Resuspended by Ship Docking in San Diego Bay.* Paper presented at the Proceedings of the 4th International Conference on Hydroscience & Engineering.

Wang, P. F., D. B. Chadwick, C. Johnson, and J. Grovhoug. (2006). *Modeling Copper and Biocide Concentrations from Hull Paint Leachate in San Diego Bay* (Technical Report 1935). San Diego, CA: SPAWAR Systems Center San Diego.

Wang, P. F., B. Chadwick, W. Choi, C. Jones, W. Wen, and M. Yoshioka. (2009). *Resuspension and Transport of Sediments by Propeller Wash in Pearl Harbor.* Paper presented at the Fifth International Conference on Remediation of Contaminated Sediments February 2–5. Jacksonville, FL.

Wang, Z., Z. Liu, K. Xu, L. M. Mayer, Z. Zhang, A. S. Kolker, and W. Wu. (2014b). Concentrations and sources of polycyclic aromatic hydrocarbons in surface coastal sediments of the northern Gulf of Mexico. *Geochemical Transactions, 15*(1), 1.

Waters, D. F., C. P. Cadou, and W. E. Eagle. (2013). Quantifying unmanned undersea vehicle range improvement enabled by aluminum–water power system. *Journal of Propulsion and Power, 29*(3), 675–685.

Watters, D. L., M. M. Yoklavich, M. S. Love, and D. M. Schroeder. (2010). Assessing marine debris in deep seafloor habitats off California. *Marine Pollution Bulletin, 60*, 131–138.

White, C., J. A. Sayer, and G. M. Gadd. (1997). Microbial solubilization and immobilization of toxic metals: Key biogeochemical processes for treatment of contamination. *FEMS Microbiology Reviews, 20*, 503–516.

Wiseman, W. J., Jr., and R. W. Garvine. (1995). Plumes and coastal currents near large river mouths. *Estuaries, 18*(3), 509–517.

Wren, P. A., and L. A. Leonard. (2005). Sediment transport on the mid-continental shelf in Onslow Bay, North Carolina during Hurricane Isabel. *Estuarine, Coastal and Shelf Science, 63*(1–2), 43–56.

Wright, S. L., R. C. Thompson, and T. S. Galloway. (2013). The physical impacts of microplastics on marine organisms: A review. *Environmental Pollution, 178*, 483–492.

Wu, J., and E. Boyle. (1997). Lead in the western North Atlantic Ocean: Completed response to leaded gasoline phaseout. *Geochimica et Cosmochimica Acta, 61*(15), 3279–3283.

Zhao, J. S., C. W. Greer, S. Thiboutot, G. Ampleman, and J. Hawari. (2004a). Biodegradation of the nitramine explosives hexahydro-1,3,5-triazine and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine in cold marine sediment under anaerobic and oligotrophic conditions. *Canadian Journal of Microbiology, 50*, 91–96.

Zhao, J. S., J. Spain, S. Thiboutot, G. Ampleman, C. Greer, and J. Hawari. (2004b). Phylogeny of cyclic nitramine-degrading psychrophilic bacteria in marine sediment and their potential role in the natural attenuation of explosives. *FEMS Microbiology Ecology, 49*(3), 349–357.

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3.3 Vegetation

PREFERRED ALTERNATIVE SYNOPSIS

The United States Department of the Navy considered all potential stressors that vegetation could be exposed to from the Proposed Action. The following conclusions have been reached for the Preferred Alternative (Alternative 1):

- Acoustics: Acoustic stressors are not applicable to vegetation due to the lack of hearing capabilities of vegetation and will not be analyzed further in this section.
- Explosives: Explosives could affect vegetation by destroying individuals or damaging parts of individuals; however, there would be no persistent or large-scale effects on the growth, survival, distribution, or structure of vegetation.
- Energy: Energy stressors are not applicable to vegetation because vegetation have a limited sensitivity to energy stressors and will not be analyzed further in this section.
- Physical Disturbance and Strike: Physical disturbance and strike could affect vegetation by destroying individuals or damaging parts of individuals; however, there would be no persistent or large-scale effects on the growth, survival, distribution, or structure of vegetation.
- Entanglement: Entanglement stressors are not applicable to vegetation because of the sedentary nature of vegetation and will not be analyzed further in this section.
- Ingestion: Ingestion stressors are not applicable to vegetation because vegetation are photosynthetic organisms and will not be analyzed further in this section.
- Secondary: Project effects on sediment or water quality would be minor, temporary, and localized, and could have small-scale secondary effects on vegetation; however, there would be no persistent or large-scale effects on the growth, survival, distribution, or structure of vegetation.

3.3.1 Introduction

This section provides analysis of potential impacts on vegetation found in the Hawaii-Southern California Training and Testing (HSTT) Study Area (Study Area) and an introduction to the species that occur in the Study Area.

Vegetation includes diverse taxonomic/ecological groups of marine algae throughout the Study Area, as well as flowering plants in the coastal and inland waters. For this Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS) analysis, vegetation has been divided into eight groups that encompass taxonomic categories, distributions, and ecological relationships. These groups include blue-green algae (phylum Cyanobacteria), dinoflagellates (phylum Dinophyta), green algae (phylum Chlorophyta), coccolithophores (phylum Haptophyta), diatoms (phylum Ochrephyta), brown algae (phylum Phaeophyta), red algae (phylum Rhodophyta), and vascular plants (phylums Tracheophyta and Spermatophyte). Furthermore, the analysis considers the distribution of vegetation based on oceanic features and vertical distribution. Open-ocean oceanographic features of the Study Area include the North Pacific Subtropical Gyre and the North Pacific Transition Zone. Additionally, vertical distribution within the water column or the bottom substrate is considered.

The types of vegetation present in the Study Area are described in this section and the affected environmental baseline is discussed in Section 3.3.2 (Affected Environment). The analysis of environmental consequences is presented in Section 3.3.3 (Environmental Consequences), and the potential impacts of Alternative 1 and Alternative 2 are summarized in Section 3.3.4 (Summary of Potential Impacts on Vegetation).

The distribution and condition of offshore abiotic (non-living) substrates necessary for attached macroalgae and rooted vascular plants (e.g., seagrass), and the impact of stressors on those substrates are described in Section 3.5 (Habitats). Additional information on the biology, life history, and conservation of marine vegetation can be found on the websites of the following agencies and groups:

- National Marine Fisheries Service
- Conservation International
- Algae base
- National Museum of Natural History

3.3.2 Affected Environment

Three subsections are included in this section. General background information is given in Section 3.3.2.1 (General Background), which provides brief summaries of habitat use and threats that affect or have the potential to affect natural communities of vegetation within the Study Area. Although there are no species listed under the Endangered Species Act (ESA), Section 3.3.2.2 (Endangered Species Act Listed Species) would list species that were proposed, candidates, or listed under the ESA. General types of vegetation that are not listed under the ESA are briefly reviewed in Section 3.3.2.3 (Species Not Listed Under the Endangered Species Act).

3.3.2.1 General Background

3.3.2.1.1 Habitat Use

Factors that influence the distribution and abundance of vegetation in the coastal and open ocean areas of the Study Area are the availability of light and nutrients, water quality, water clarity, salinity level, seafloor type (important for rooted or attached vegetation), storms and currents, tidal schedule, temperature, and grazing by herbivores (Green & Short, 2003).

Marine ecosystems depend almost entirely on the energy produced by marine vegetation through photosynthesis (Castro & Huber, 2000), which is the transformation of the sun’s energy into chemical energy. In the photic zone of the open-ocean and coastal waters, marine algae and flowering plants have the potential to provide oxygen and habitat for many organisms in addition to forming the base of the marine food web (Dawes, 1998).

The affected environment comprises two major ecosystem types, the open ocean and coastal waters; and two major habitat types, the water column and bottom (benthic) habitat. Vegetation grows only in the sunlit portions of the open ocean and coastal waters, referred to as the “photic” or “euphotic” zone, which extends to maximum depths of roughly 660 feet (ft.) (200 meters [m]). Because depth in most of the open ocean exceeds the euphotic zone, benthic habitat for vegetation is limited primarily to the coastal waters.

The euphotic zones of the water column in the Study Area are inhabited by phytoplankton, single-celled (sometimes filamentous or chain forming), free-floating algae primarily of four groups (Table 3.3-1) including diatoms, blue-green algae, dinoflagellates, and coccolithophores. Microscopic algae can grow down to depths with only 1 percent of surface light penetration (Nybakken, 1993). These important groups are summarized below (Levinton, 2009):

- Diatoms dominate the phytoplankton at high latitudes. They are single-celled organisms with shells made of silica, which sometimes form chains of cells.
- Blue-green algae (which are photosynthetic bacteria) are found in and may dominate nearshore waters of restricted circulation and/or brackish (low salinity) waters as well as the open ocean. Blue-green algae convert atmospheric nitrogen to ammonia, which can then be taken up by marine vascular plants and animals.
- Dinoflagellates are covered with cellulose plates and dominate the phytoplankton at low latitudes year round and at higher latitudes in summer and autumn. Rapid population increases in dinoflagellates can result in "red tides" and "harmful algal blooms." Toxins produced by some dinoflagellates accumulate in the animals that consume them and can cause poisoning among the higher level human and marine mammal consumers.
- Coccolithohores are nearly spherical and secrete a skeleton of calcium carbonate plates. They can be dominant in the phytoplankton of tropical as well as sub-polar seas. They account for approximately one third of calcium carbonate production in the entire ocean.

Other types of algae that can also be abundant in the phytoplankton, although usually less so than the four groups above, include silicoflagellates, green algae, and cryptomonad flagellates (Levinton, 2013).

Vascular plants in the Study Area include seagrasses, cordgrasses, and mangroves, all of which have more limited distributions than algae (which are non-vascular), and typically occur in intertidal or shallow (< 40 ft.) subtidal waters (Green & Short, 2003). The relative distribution of seagrasses is influenced by the availability of suitable substrate occurring in low-wave energy areas at depths that allow sufficient light exposure for growth. Seagrasses as a rule require more light than algae, generally 15–25 percent of surface incident light (Fonseca et al., 1998; Green & Short, 2003). Seagrass species distribution is also influenced by water temperatures (Spalding et al., 2003).

Emergent wetland vegetation of the Study Area is typically dominated by cordgrasses (*Spartina foliosa*), which form dense colonies in salt marshes that develop in temperate areas in protected, low-energy environments on soft substrate, along the intertidal portions of coastal lagoons, tidal creeks or rivers, or estuaries, wherever the sediment is adequate to support plant root development (Mitsch et al., 2009).

In Hawaii, there are two species of seagrasses and at least 204 species of red algae, 59 species of brown algae, and 92 species of green algae. Seaweeds are important in native Hawaiian culture and are used in many foods (Preskitt, 2002b, 2010). Red coralline algae and green calcareous (calcium-containing) algae (*Halimeda* species) secrete calcareous skeletons that bind loose sediments in coral reefs in Hawaii (Spalding et al., 2003). In the Northwestern Hawaiian Islands, beyond the coral reef habitat, algal meadows dominate the terraces and banks at depths of 98.4–131.2 ft. (30–40 m). There are approximately 1,740.62 square miles (4,507 square kilometers) of this type of substrate, an estimated 65 percent of which is covered by algal meadows (Parrish & Boland, 2004). Surveys from 2007 to 2016 generally showed a slightly higher percent cover of macroalgae compared to hard coral in the Northwestern Hawaiian Islands. However, higher percent cover of corals compared to macroalgae was observed along the main Hawaiian Islands (McCoy et al., 2016).

Marine vegetation along the California coast is represented by more than 700 species and varieties of seaweeds (such as corallines and other red algae, brown algae including kelp, and green algae), seagrasses (Leet et al., 2001; Wyllie-Echeverria & Ackerman, 2003), and canopy-forming kelp species

(Wilson, 2002). Extensive mats of red algae provide habitat in areas of exposed sediment along the California coast (U.S. Department of the Navy, 2013). Refer to Section 3.3.2.3 (Species Not Listed Under the Endangered Species Act) for distribution information.

3.3.2.1.2 General Threats

Environmental stressors on marine vegetation are products of human activities (e.g., industrial, residential, and recreational activities) and natural occurrences (e.g., storms, surf, and tides). Species-specific information is discussed, where applicable, in Sections 3.3.3.4 (Physical Disturbance and Strike Stressors) and 3.3.3.7 (Secondary Stressors), and the cumulative impacts from these threats are analyzed in Chapter 4 (Cumulative Impacts).

Human-made stressors that act on marine vegetation include excessive nutrient input (such as fertilizers), siltation (the addition of fine particles to the ocean), pollution (oil, sewage, trash) (Mearns et al., 2011), climate change (Arnold et al., 2012; Doney et al., 2012; Martinez et al., 2012; Olsen et al., 2012), fishing practices (Mitsch et al., 2009; Steneck et al., 2002), shading from structures (National Marine Fisheries Service, 2002), harvesting (Wilson, 2002), habitat degradation from construction and dredging, and introduced or invasive species (Hemminga & Duarte, 2000; Spalding et al., 2003) The seagrass, cordgrass, and mangrove taxonomic group is often more sensitive to stressors than the algal taxonomic groups. The great diversity of algae makes generalization difficult, but overall, algae are resilient and colonize disturbed environments created by stressors (Levinton, 2009).

Marine algae and vascular plants are important ecologically and economically, providing an important source of food, essential ecosystem services (e.g., coastal protection, nutrient recycling, food for other animals, and habitat formation), and income from tourism and commercial fisheries (Spalding et al., 2001).

3.3.2.1.2.1 Water Quality

Water quality in the Study Area may be impacted by the introduction of harmful contaminants from diverse sources unrelated to either action alternative. Common ocean pollutants include toxic compounds such as metals, pesticides, herbicides, and other organic chemicals, excess nutrients from fertilizers and sewage, detergents, oil, plastics, and other solids. Coastal pollution and agricultural runoff may cause toxic red tide events in the Study Area (Hayes et al., 2007). Coastal development and pollution, particularly storm water runoff and point source discharges, affect water quality of bays and coastal areas throughout the world. Depending on the proximity to and nature of the discharge, sediment and water quality may be degraded, which in turn can impact marine vegetation communities. Erosion and sedimentation may also affect sediment and water quality of coastal areas during storm runoff from urban streets into rivers and streams.

Oil in runoff from land-based sources, natural seeps, and accidental spills (such as offshore drilling and oil tanker leaks) are some of the major sources of oil pollution in the marine environment (Levinton, 2009). The type and amount of oil spilled, weather conditions, season, location, oceanographic conditions, and the method used to remove the oil (containment or chemical dispersants) are some of the factors that determine the severity of the impacts. Sensitivity to oil varies among species and within species, depending on the life stage; generally, early life stages are more sensitive than adult stages (Hayes et al., 1992). The tolerance to oil pollutants varies among the types of marine vegetation, but their exposure to sources of oil pollutants makes them all vulnerable.

Oil pollution, as well as chemical dispersants used in response to oil spills, can impact seagrasses directly by smothering the individuals, or indirectly by lowering their ability to combat disease and other stressors (U.S. National Response Team, 2010). Seagrasses that are totally submerged are less susceptible to oil spills since they largely escape direct contact with the pollutant. Depending on various factors, oil spills can result in a range of effects from no impact to long-lasting impacts, such as decreases in eelgrass density (Kenworthy et al., 1993; Peterson, 2001). Algae are relatively resilient to oil spills, while mangroves are highly sensitive to oil exposure. Contact with oil can cause death, leaf loss, and failure to germinate (Hoff et al., 2002). Salt marshes can also be severely impacted by oil spills, with long-term effects (Culbertson et al., 2008).

3.3.2.1.2.2 Commercial Industries

Green seaweed is harvested for human consumption in Hawaii's coastal waters. Common species harvested include *Ulva fasciata, Enteromorpha prolifera,* and *Codium edule* (Preskitt, 2002b, 2010). Edible brown seaweeds that are collected in Hawaii include *Sargassum echinocarpum* and *Dictyopteris plagiograma* (Preskitt, 2002a). The State of Hawaii Department of Land and Natural Resources regulates the collection of seaweeds.

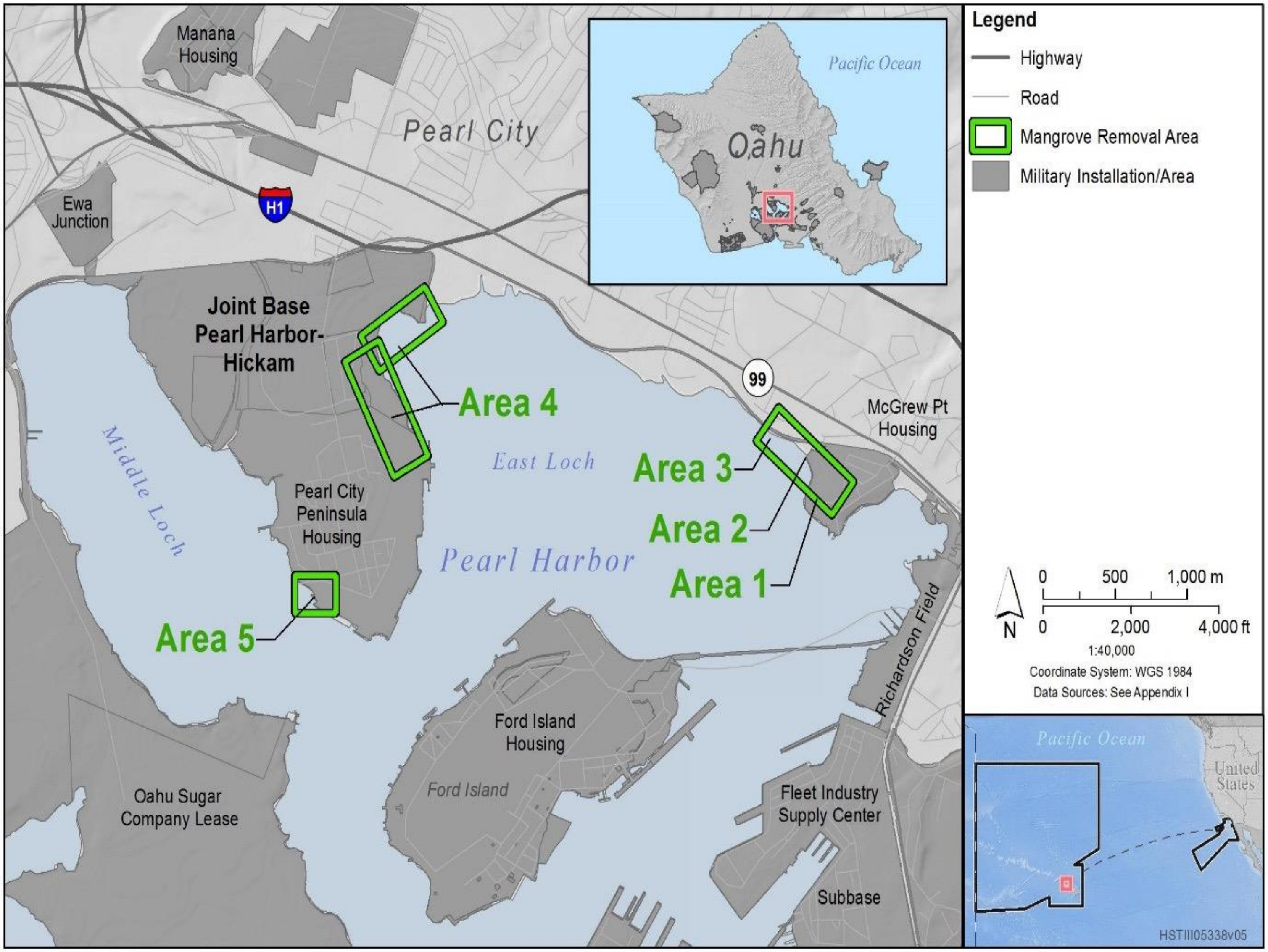
Although historically important, large-scale harvesting of kelp beds no longer occurs along the California coast. Small-scale commercial operations, however, continue to harvest kelp, primarily for abalone feed (Wilson, 2002). The California Department of Fish and Game, which issues exclusive leases to harvest designated beds for up to 20 years, manages kelp harvesting. Although they are not limited in the amount, California regulations prohibit commercial harvesters from cutting attached *Macrocystis pyrifera* and *Nereocystis luetkeana* (giant and bull) kelp from deeper than 4 ft. (1.2 m) below the water's surface (14 California Code of Regulations 165[c][2]), which protects the reproductive structures at the kelp's base and allows vegetative re-growth (Wilson, 2002).

3.3.2.1.2.3 Disease and Parasites

Marine algae and vascular plants may be susceptible to disease caused by other marine organisms, which may impact individuals or populations. In particular, eelgrass is vulnerable to a wasting disease caused by a marine pathogen that has caused devastating population loss in the past (Ralph & Short, 2002). Certain species of microscopic algae (e.g., dinoflagellates and diatoms) can form algal blooms, which can pose serious threats to human health and wildlife species. Harmful algal blooms can deplete oxygen within the water column and block sunlight that other organisms need to live, and some algae within algal blooms release toxins that are dangerous to human and ecological health (Center for Disease Control and Prevention, 2004). These algal blooms have a negative economic impact of hundreds of millions of dollars annually worldwide (National Centers for Coastal Ocean Science, 2010). Additional information on harmful algal blooms can be accessed on the Centers for Disease Control and the National Oceanic and Atmospheric Administration websites.

3.3.2.1.2.4 Invasive Species

Invasive vegetation species are present throughout the Study Area. The red mangrove (*Rhizophora mangle*) is an invasive species in Hawaii and various resource agencies and organizations (e.g., Hawaii Department of Land and Natural Resources, Pacific Cooperative Studies Unit, Malama O Puna) have eradication programs targeting the red mangrove and other mangrove infestations (Figure 3.3-1). First introduced primarily to stabilize coastal flats in the early 1900s (Allen, 1998), the red mangrove is native to Florida and the Caribbean. Since the introduction of this species, mangroves have invaded intertidal



Source: U.S. Department of the Navy (2014)

Figure 3.3-1: Areas Subject to Mangrove Removal in Pearl Harbor

areas formerly devoid of trees. In 2013 and 2014, the United States (U.S.) Department of the Navy (Navy) completed several mangrove removal actions in Pearl Harbor (Figure 3.3-1), which enhanced native sedge growth among other environmental benefits (U.S. Department of the Navy, 2014).

Invasive marine green algal species are found in coastal waters of the Study Area. The invasive green algae, *Avrainvillea amadelpha,* has been recorded in the main Hawaiian Islands (Preskitt, 2010). Invasive green algae represent a serious threat to coral reefs, and may displace, outcompete, or hybridize with non-invasive native green algae species, resulting in the loss of native biodiversity or alteration of ecosystem processes. Representative non-native invasive species of red algae in the Hawaii portion of the Study Area include *Acanthophora spicifera*, *Gracilaria salicornia*, *Hypnea musciformis*, *Kappaphycus alvarezii*, and *Gracilaria tikvahiae* (Smith et al., 2002).

Caulerpa taxifolia and *Codium fragile tomentosoide* are invasive green algal species found in the southern California portion of the Study Area (Dobroski et al., 2015; Gagnon et al., 2015). In addition, *Sargassum muticum* (Japanese wireweed) and *Sargassum horneri* (devil weed) are invasive brown algal species found within the California portion of the study area (Dobroski et al., 2015; Marks et al., 2015). *Undaria pinnatifida* (or wakame), which is an edible seaweed native to Japan, is an invasive species that is also found along the California coast (Dobroski et al., 2015; Global Invasive Species Database, 2005). Devil weed and wakame are found in San Diego County and have exhibited characteristics of successful invaders such as establishing in new areas, spreading locally, and persisting through multiple generations. They primarily occur in harbors but have also been found in open coast sites. This rapid and uncontrolled spread has ecological and economic consequences that will require further research (Kaplanis et al., 2016).

Department of Defense has implemented projects to control invasive microalgae at critical control points (specific areas where spread and transport of invasive species are likely to occur). For example, in 2011, an experimental macroalgae cleanup occurred in an infested area of Mokapu Peninsula, at the sea plane ramps. Lessons learned from this experiment were discussed with Sikes Act partners and provided the basis for tackling more ambitious projects in the future. A slow and steady phased approach is often the most successful in making progress with controlling invasive speicies, based on the expeiences of the Marine Corps Base at Mokapu Peninsula (Marine Corps Base Hawaii, 2011).

3.3.2.1.2.5 Climate Change

The impacts of anthropogenically induced climate change on the marine environments include rising sea levels, ocean acidification, increased sea temperature, and an increase in severe weather events. All of these changes may have impacts on vegetation in the Study Area.

Rising sea levels will alter the amount of sunlight reaching various areas, which may decrease the photosynthetic capabilities of vegetation in those areas. However, the fast growth and resilient nature of vegetation may enable most species to adapt to these changes (Harley et al., 2006). Increased sea temperature may lead to several impacts that could affect vegetation. Warmer waters may lead to a greater stratification in the water column, which may support harmful algal blooms (Lehmköster, 2015). The stratification may also inhibit upwelling, as seen during El Niño events, which would prevent nutrients from circulating to the surface (Lehmköster, 2015). Additionally, increased sea temperatures may lead to changes in the composition of vegetation communities (Schiel et al., 2004). These changes in community composition could impact biological interactions, including the mutualism between reef-building corals and algae (Doney et al., 2012). These indirect and direct impacts of climate change that decrease coral reef habitat may enable vegetation to overtake areas that were previously biogenic reef habitat (Hughes et al., 2007; Pandolfi et al., 2005). Increases in severe weather events may lead to increased erosion and sedimentation in the marine environments and higher energy wave action that could increase impacts on vegetation by physical disturbance, such as marine vascular plants becoming unrooted.

Vegetation is susceptible to water quality changes from erosion and disturbances from storm events. Increased storm events are expected to impact species diversity in kelp ecosystems (Byrnes et al., 2011). The impacts of ocean acidification on vegetation are poorly understood (Harley et al., 2006). Ocean acidification may impact the ecological function of coralline algae by decreasing habitat-forming capabilities (Ragazzola et al., 2016).

3.3.2.1.2.6 Marine Debris

Marine debris (especially plastics) is a threat to many marine ecosystems, particularly in coastal waters adjacent to urban development. Microplastics (generally considered to be particles less than 5 millimeters [mm] in size), which may consist of degraded fragments of larger plastic items or intentionally manufactured items (e.g., abrasive plastic beads found in some personal care products or used in blast-cleaning), are of concern because of their durability, long lifespan, and potential to enter marine food webs (Setala et al., 2016). Marine debris may injure marine vegetation if it is large and is pulled around by tidal influences and currents (Gregory, 2009). Refer to Section 3.2 (Sediments and Water Quality) for a more detailed discussion of marine debris and the associated effects on water quality.

Marine debris, including large amounts of plastic, is present throughout the entire Study Area (Cooper & Corcoran, 2010; Dameron et al., 2007). The Hawaiian Archipelago is located within the North Pacific Gyre, which consolidates debris originating in various areas of the Pacific Ocean. Bottom trawl studies of anthropogenic marine debris on the continental shelf and upper slope of the U.S. West Coast (Washington to Southern California) revealed that debris was widespread throughout the area investigated (Keller et al., 2010). Military expended materials (e.g., ammunition boxes, helmets, and rocket boosters and launchers) were the highest contributors to recovered metals in deeper waters off California in areas known for Navy activities and military dump sites, including around Catalina and San Clemente Islands. Recent studies in the Southern California Bight found that marine debris (primarily plastic) occurred in about one-third of seafloor areas surveyed (Moore et al., 2016). Microplastic particles were more prevalent in shallow nearshore areas (ports, marinas, bays, and estuaries) than in offshore areas.

3.3.2.2 Endangered Species Act Listed Species

There are no species of vegetation listed as endangered, threatened, candidate, or proposed under the ESA in the Study Area.

3.3.2.3 Species Not Listed Under the Endangered Species Act

Thousands of vegetation species occur in the Study Area and none are listed under the ESA (Table 3.3-1).

Table 3.3-1: Major Groups of Vegetation in the Study Area

Marine Vegetation Groups		***Vertical Distribution in the Study Area***[2]		
Common Name[1] ***(Taxonomic Group)***	***Description***	***Open Ocean***	***Coastal Waters***	***Bays and Harbors***
Blue-green algae (phylum Cyanobacteria)	Photosynthetic bacteria that are abundant constituents of phytoplankton and benthic algal communities, accounting for the largest fraction of carbon and nitrogen fixation by marine vegetation; existing as single cells or filaments, the latter forming mats or crusts on sediments and reefs.	Water column	Water column, bottom	Water column, bottom
Dinoflagellates (phylum Dinophyta [Pyrrophyta])	Most are single-celled, marine species of algae with two whip-like appendages (flagella). Some live inside other organisms, and some produce toxins that can result in red tide or ciguatera poisoning.	Water column	Water column	Water column
Green algae (phylum Chlorophyta)	May occur as single-celled algae, filaments, and seaweeds.	Sea surface	Water column, bottom	Water column, bottom
Coccolithophores (phylum Haptophyta [Chrysophyta, Prymnesiophyceae])	Single-celled marine phytoplankton that surround themselves with microscopic plates of calcite. They are abundant in the surface layer and are a major contributor to global carbon fixation.	Water column	Water column	Water column
Diatoms (phylum Ochrophyta [Heterokonta, Chrysophyta, Bacillariophyceae])	Single-celled algae with a cylindrical cell wall (frustule) composed of silica. Diatoms are a primary constituent of the phytoplankton and account for up to 20 percent of global carbon fixation.	Water column	Water column, bottom	Water column, bottom
Brown algae (phylum Phaeophyta [Ochrophyta])	Brown algae are large multi-celled seaweeds that form extensive canopies, providing habitat and food for many marine species.	Water column	Water column, bottom	Water column, bottom
Red algae (phylum Rhodophyta)	Single-celled algae and multi-celled large seaweeds; some form calcium deposits.	Water column	Water column, bottom	Water column, bottom

Table 3.3-1: Major Groups of Vegetation in the Study Area (continued)

Marine Vegetation Groups		*Vertical Distribution in the Study Area*[2]		
Common Name*[1] *(Taxonomic Group)	***Description***	***Open Ocean***	***Coastal Waters***	***Bays and Harbors***
Vascular plants (phylum Tracheophyta, Spermatophyta)	Includes seagrasses, cordgrass, mangroves and other rooted aquatic and wetland plants in marine and estuarine environments, providing food and habitat for many species.	None	Bottom	Bottom

[1]Taxonomic groups are based on Roskov et al. (2015); Ruggiero and Gordon (2015); and the Integrated Taxonomic Information System. Alternative classifications are in brackets []. Phylum and division may be used interchangeably.
[2]Vertical distribution in the Study Area is characterized by open-ocean oceanographic features (North Pacific Subtropical Gyre and North Pacific Transition Zone) or by coastal waters of two large marine ecosystems (California Current and Insular Pacific-Hawaiian).

3.3.2.3.1 Blue-Green Algae (Phylum Cyanobacteria)

Blue-green algae are single-celled, photosynthetic bacteria that inhabit the photic zone and seafloors of the world's oceans (Roskov et al., 2015). Blue-green algae are key primary producers in the marine environment and provide valuable ecosystem services such as producing oxygen and nitrogen. The blue-green algae, *Prochlorococcus* species, is responsible for a large portion of the global oxygen production by photosynthetic organisms. Other species of blue-green algae have specialized cells that convert nitrogen gas into a form that can be used by other marine plants and animals (nitrogen fixation) (Hayes et al., 2007). In the nutrient-poor waters of coral reef ecosystems within the Hawaiian portion of the Study Area, blue-green algae are an important source of food for marine species. Diverse grazers, particularly large grazers such as sea urchin and fish, as well as mesoherbivores (e.g., small fish and crabs) and microherbivores (e.g., amphipods, gastropods, and polychaetes) are known to feed on blue-green algae and may influence algal community structures. Physical and biological disturbances to algae may, ultimately, shift the algal community structure to more disturbance-tolerant forms of algae (e.g., turfs and crusts) (Cheroske et al., 2000).

3.3.2.3.2 Dinoflagellates (Phylum Dinophyta)

Dinoflagellates are single-celled organisms with two flagella (whip-like structures used for locomotion) in the phylum Dinophyta (Roskov et al., 2015). Dinoflagellates are predominantly marine algae, with an estimated 1,200 species living in surface waters of the ocean worldwide (Castro & Huber, 2007). Most dinoflagellates can use the sun's energy to produce food through photosynthesis and can ingest small food particles. Photosynthetic dinoflagellates are important primary producers in coastal waters (Waggoner & Speer, 1998). Organisms such as zooplankton (microscopic animals that drift passively in the water column) feed on dinoflagellates.

Dinoflagellates are also valuable for their close relationship with some invertebrates, most notably reef-building corals (see Section 3.4, Invertebrates). Some species of dinoflagellates (zooxanthellae) live inside corals. This mutually beneficial relationship provides shelter and food (in the form of coral waste products) for the dinoflagellates; in turn, the corals receive essential nutrients produced by dinoflagellates (Spalding et al., 2007). Dinoflagellates cause some types of harmful algal blooms, which result from sudden increases in nutrients (e.g., fertilizers) from land into the ocean or changes in temperature and sunlight (Levinton, 2009).

3.3.2.3.3 Green Algae (Phylum Chlorophyta)

Green algae are single-celled organisms in the phylum Chlorophyta that may form large colonies of individual cells (Roskov et al., 2015). Green algae may be found in the water column and benthic habitats. Only 10 percent of the estimated 7,000 species of green algae are found living in the marine environment (Castro & Huber, 2000). These species are important primary producers that play a key role at the base of the marine food web. Green algae are found in areas with a wide range of salinity, such as bays and estuaries, and are eaten by various organisms, including zooplankton and snails.

3.3.2.3.4 Coccolithophores (Phylum Haptophyta)

Coccolithophores are single-celled phytoplankton that are especially abundant in tropical oceans but also bloom seasonally at higher latitudes. Up to 200 species have been described in the scientific record, 30–40 of which are common in the sedimentary record (Giraudeau & Beaufort, 2007). Coccolithophores are found in the water column as free-floating phytoplankton. They are nearly spherical and covered with plates made of calcite (calcium carbonate), which account for approximately one-third of calcium carbonate production in the entire ocean. They are an often-abundant component of the phytoplankton and account for a large fraction of primary production and carbon sequestration in the ocean. Blooms produce a strong bluish-white reflection that may cover thousands of square miles (Levinton, 2013).

3.3.2.3.5 Diatoms (Phylum Ochrophyta)

Diatoms are single-celled organisms with cell walls made of silicon dioxide. Two major groups of diatoms are generally recognized, centric diatoms and pinnate diatoms. Centric diatoms exhibit radial symmetry (symmetry about a point), while the pinnate diatoms are bilaterally symmetrical (symmetry about a line). Diatoms are found in the water column and benthic habitats in coastal areas. Diatoms such as *Coscinodiscus* species commonly occur throughout the Study Area. Some strains of another genus of diatoms, Pseudonitzschia, produce a toxic compound called domoic acid. Humans, marine mammals, and seabirds become sick or die when they eat organisms that feed on Pseudonitzschia strains that produce the toxic compound. The southern California portion of the Study Area, off the coasts of Los Angeles and Orange Counties, had some of the highest concentrations of the toxic compound ever recorded in United States waters (Schnetzer et al., 2007). *Pseudo-nitzschia* blooms in the Southern California Bight during 2003 and 2004 were linked to stranding over 1,400 marine mammals (Schnetzer et al., 2007). Pollutants carried from land to the ocean by rainwater (Kudela & Cochlan, 2000), and decreases in the movement of cool, nutrient-rich waters by the wind are believed to be the main causes of these harmful algal blooms in the southern California portion of the Study Area (Kudela et al., 2004).

3.3.2.3.6 Brown Algae (Phylum Phaeophyta)

Brown and golden-brown algae are large multi-celled marine species with structures varying from fine filaments to thick leathery forms (Castro & Huber, 2000). Most species are attached to the seafloor in coastal waters (such as kelp), although a species with both attached and free-floating forms (*Sargassum muticum* [invasive]) occurs within the southern California portion of the Study Area.

3.3.2.3.6.1 Kelp

Kelp is a general term that refers to brown algae of the order Laminariales. Kelp plants are made of three parts: the leaf-like blade(s), the stipe (a stem-like structure), and the holdfast (a root-like structure that anchors the plant to the bottom). The following five species of canopy-forming kelp occur in the coastal waters of the California coast: giant kelp, bull kelp, elk horn kelp (*Pelagophycus porra*), feather boa kelp (*Egregia menziesii*), and chain bladder kelp (*Stephanocystis osmundacea*). The dominant kelp in the southern California portion of the Study Area is giant kelp. Since the first statewide survey in 1967, the total area of kelp canopies has generally declined; the greatest decline occurred along the mainland coast of southern California (Wilson, 2002; Young et al., 2016). The canopy coverage of kelp beds varies under changing oceanographic conditions, and is also influenced by the level of harvesting, invasive species, coastal pollution, and development (Wilson, 2002).

Kelp is the most conspicuous brown algae occurring extensively along the coast in the southern California portion of the Study Area. The giant kelp can live up to eight years and can reach lengths of197 ft. (60 m). The leaf-like fronds can grow up to 23.6 inches (60 centimeters) per day (Leet et al., 2001). Bull kelp (*Nereocystis luetkeana*) growth can exceed 3.9 inches (10 centimeters) per day. Bull kelp attaches to rocky substrates and can grow up to 164 ft. (50 m) in length in nearshore areas. In turbid waters, the offshore edge of kelp beds occurs at depths of 49–59 ft. (15–18 m), which can extend to a depth of 98.4 ft. (30 m) in the clear waters around the Channel Islands off the coast of southern California (Wilson, 2002). The kelp beds along the California coast and off the Channel Islands are the most extensive and elaborate submarine forests in the world (Rodriguez et al., 2001). El Niño events tend to have a direct influence on the region and have the potential to affect kelp populations, especially when these events are major (Grove et al., 2002).

3.3.2.3.6.2 Sargassum

Sargassum is a genus of brown algae that generally inhabits shallow waters and coral reefs within the Study Area. *Sargassum echinocarpum* (Limu kala) is a native species of Hawaii and is usually found within tide pools and on reef flats. Meanwhile, *Sargassum agardhianum* is native to California.

Two introduced species of *Sargassum* also inhabit the southern California portion of the Study Area – *Sargassum muticum* and *Sargassum horneri*. The brown alga *Sargassum muticum* was introduced from the Sea of Japan and now occupies portions of the California coast (Dobroski et al., 2015; Monterey Bay Aquarium Research Institute, 2009). *Sargassum horneri* is native to western Japan and Korea. Since *Sargassum horneri* was first discovered in Long Beach Harbor in 2003, the species continues to increase its spatial extent and can now be found near harbors and anchorages from Santa Barbara, California, to Isla Natividad in Baja California (Mexico) (Marks et al., 2015). Specifically, *Sargassum horneri* has been found in the Study Area, in places like San Diego and the Channel Islands (U.S. Department of the Navy, 2013). Both *Sargassum muticum* and *Sargassum horneri* are present in the Study Area.

3.3.2.3.7 Red Algae (Phylum Rhodophyta)

Red algae are predominately marine, with approximately 4,000 species worldwide (Castro & Huber, 2000). Red algal species exist in a range of forms, including single and multicellular forms (Roskov et al., 2015), from fine filaments to thick calcium carbonate crusts. Within the Study Area, they occur in the water column and bottom habitats of coastal waters, primarily in reef environments and intertidal zones of Hawaii and California. Common native species in Hawaii include *Laurencia* species, *Gracilaria coronopifolia*, *Hypnea cervicornis*, and *Gracilaria parvispora*. Many red algae species contribute to reef formation by hardening the reef (by producing calcium carbonate) and by cementing coral fragments (Veron, 2000), and are food for various sea urchins, fishes, and chitons. In California waters, common species include *Endocladia muricata*, *Mastocarpus papillatus*, and species of *Mazaella*.

3.3.2.3.8 Seagrasses, Cordgrasses, and Mangroves (Phylum Spermatophyta)

Seagrasses, cordgrasses, and mangroves are flowering marine plants in the phylum Spermatophyta (Roskov et al., 2015). These marine flowering plants create important habitat and are a food source for many marine species. These marine vascular plants are found only in coastal waters, attached to the bottom.

3.3.2.3.8.1 Seagrasses

Seagrasses are unique among flowering plants because they grow submerged in shallow marine environments. Except for some species that inhabit the rocky intertidal zone, seagrasses grow in shallow, subtidal, or intertidal sediments, and can extend over a large area to form seagrass beds (Garrison, 2004; Phillips & Meñez, 1988). Seagrass beds provide important ecosystem services as a structure-forming keystone species (Arnold et al., 2012; Buhl-Mortensen et al., 2010; U.S. National Response Team, 2010). They provide suitable nursery environment for commercially important organisms (e.g., crustaceans, fish, and shellfish) and are also a food source for numerous species (e.g., turtles) (Nagaoka et al., 2012). Seagrass beds combat coastal erosion, promote nutrient cycling through the breakdown of detritus (Dawes et al., 1997; Dawes, 1998), and improve water quality. Seagrasses also contribute a high level of primary production to the marine environment, which supports high species diversity and biomass (Spalding et al., 2003). Seagrasses are uprooted by dredging and scarred by boat propellers (Hemminga & Duarte, 2000; Spalding et al., 2003), which can take years to recover.

In Hawaii, the most common seagrasses are Hawaiian seagrass (*Halophila hawaiiana*) and paddle grass (*Halophila decipiens*). Hawaiian seagrass is a native species found at less than 3.3 ft. (1 m) in subtidal, sandy areas surrounding reefs, in bays, or in fishponds. It occurs in coastal waters of Oahu near Mamala Bay (southern coast), in Maunalua Bay (southeastern coast), in Kaneohe Bay (northeast coast), in coastal waters of Maui, in the inner reef flats of southern Molokai, at Anini Beach on the northern shore of Kauai, and at Midway Atoll in the Northwestern Hawaiian Islands (Phillips & Meñez, 1988). Paddle grass is possibly a nonnative species that occurs only on Oahu in waters to 114.8 ft. (35 m) deep; it is apparently restricted to the southern shore of Oahu (Preskitt, 2001, 2002a).

Seagrasses that occur in the coastal areas of the southern California portion of the Study Area in the California Current Large Marine Ecosystem include eelgrass (*Zostera marina* and *Zostera pacifica*), surfgrass (*Phyllospadix scouleri* and *Phyllospadix torreyi*), widgeon grass (*Ruppia maritima*), and shoal grass (*Halodule wrightii*) (Jones et al., 2013; Spalding et al., 2003). The distribution of underwater vegetation is patchy along the California coast. In the southern California portion of the Study Area, eelgrass and surfgrass are the dominant native seagrasses (Wyllie-Echeverria & Ackerman, 2003).

Eelgrass covers most of the available nearshore area in San Diego Bay (Figure 3.3-2) Beds of eelgrass (Zostera marina) form an important and productive benthic habitat in San Diego Bay. Eelgrass habitats rank among the most productive habitats in the ocean (Nybakken, 1993) and are an important component of the San Diego Bay food web. As has occurred in bays and estuaries all along the Pacific coast and elsewhere in the world, eelgrass beds have suffered substantial losses and impacts due to their location in sheltered waters where human activity is concentrated. However, these losses were historic due to bay fill and deepening.

Today, various state and federal regulatory frameworks protect eelgrass beds, and any impacts are fully mitigated. For example, National Marine Fisheries Service policy recommends no net loss of eelgrass

Source: Merkel & Associates, Inc. (2014)

Figure 3.3-2: Eelgrass Beds in San Diego Bay

Notes: NB = Naval Base, NAS = Naval Air Station habitat function in California and encourages the use of eelgrass mitigation banking and in-lieu fee programs when impacts on eelgrass habitat cannot be avoided (National Oceanic and Atmospheric Administration, 2014). In San Diego Bay, the range of eelgrass bed growth is from surface to depths of approximately 10 m, depending on light levels and turbidity; eelgrass bed losses have ceased (U.S. Department of the Navy, 2013). The recovery of the eelgrass habitat within San Diego Bay is largely attributed to restoration efforts as well as reduction in waste discharges since the 1970s. San Diego Bay currently supports approximately 15 percent of the eelgrass habitat and 50 percent of total eelgrass resources for the State of California (Merkel & Associates Inc., 2014). The Navy established an eelgrass mitigation bank in San Diego Bay in 2008 as mitigation for an action that was unrelated to the Proposed Action in this EIS/OEIS.

3.3.2.3.8.2 Cordgrasses

Cordgrasses are temperate salt-tolerant land plants that inhabit salt marshes, mudflats, and other softbottom coastal habitats (Castro & Huber, 2000). Cordgrasses are not present in the Hawaii portion of the Study Area. California cordgrass (*Spartina foliosa*) can be found in salt marshes and mudflats within the southern California portion of the Study Area. The Atlantic cordgrass (*Spartina alterniflora*), which is an invasive species in California, has not been documented within the study area (Calflora, 2016; California Invasive Plant Council, 2016). Salt marshes develop in intertidal, protected low energy environments, usually in coastal lagoons, tidal creeks, rivers, or estuaries (Mitsch & Gosselink, 2007). The structure and composition of salt marshes provide important ecosystem services. Salt marshes support commercial fisheries by providing habitat for wildlife, protecting the coastline from erosion, filtering fresh water discharges into the open ocean, taking up nutrients, and breaking down or binding pollutants before they reach the ocean (Dreyer & Niering, 1995; Mitsch et al., 2009). Salt marshes also are carbon sinks (carbon reservoirs) and facilitate nutrient cycling (Bouillon et al., 2009; Chmura, 2009). Carbon sinks are important in reducing the impact of climate change (Laffoley & Grimsditch, 2009), and nutrient cycling facilitates the transformation of important nutrients through the environment. However, sinking salt marshes may damage cordgrasses, a process known as marsh subsidence.

3.3.2.3.8.3 Mangroves

Mangroves are a group of woody plants that have adapted to brackish water environments (where salt water and freshwater mix) (Ruwa, 1996). All mangrove trees have root systems that stick up in the air for oxygen intake in oxygen-poor soils and secrete salts from the leaves to process fresh water from the saline environment. Mangroves can trap sediments and pollution from terrestrial environments and can shield and stabilize coastlines from wave action. There are no native mangroves in the Hawaii portion of the Study Area. The red mangrove (*Rhizophora mangle*) and several other species of mangroves were introduced to Hawaii (Allen, 1998); these species are invasive species and are further discussed in Section 3.3.2.1.2 (General Threats). No mangroves are known to occur within California coastal environments.

3.3.3 Environmental Consequences

This section evaluates how and to what degree the activities described in Chapter 2 (Description of Proposed Action and Alternatives) potentially impact vegetation known to occur within the Study Area. In Chapter 2, Tables 2.6-1 through 2.6-5 present the baseline and proposed typical training and testing activity locations for each alternative (including number of events). General characteristics of all Navy stressors were introduced in Section 3.0.3.3 (Identifying Stressors for Analysis), and the susceptibility to stressors for living resources were introduced in Section 3.0.3.6 (Biological Resource Methods). The stressors vary in intensity, frequency, duration, and location within the Study Area.

The stressors analyzed for vegetation are:

- **Explosives**
- **Physical disturbance and strikes** (vessels and in-water devices, aircraft and aerial targets, military expended materials, seafloor devices, pile driving)
- **Secondary stressors** (explosives, explosion byproducts, and unexploded munitions; metals; chemicals; other materials; physical disturbance)

The analysis includes consideration of the mitigation that the Navy will implement to avoid potential impacts on vegetation from explosives and from physical disturbance and strikes. Mitigation for vegetation was coordinated with the National Marine Fisheries Service through the consultation processes.

3.3.3.1 Acoustic Stressors

Acoustic stressors are not applicable to vegetation because of the lack of hearing capabilities of vegetation and will not be analyzed further in this section. The physical impacts associated with the use of explosives are discussed in Section 3.3.3.2.1 (Impacts from Explosives).

3.3.3.2 Explosive Stressors

3.3.3.2.1 Impacts from Explosives

Various types of explosives are used during training and testing activities. The type, number, and location of activities that use explosives are discussed in Section 3.0.3.3.2 (Explosive Stressors). Within the coastal waters of Hawaii, most detonations would occur in waters greater than 3 nautical miles from shore in water deeper than 200 ft., although mine warfare, demolition, and some testing detonations could occur in shallow water and typically in a few specific locations. In the Southern California Range Complex, nearshore explosions occur within the Silver Strand Training Complex Boat Lanes and training areas surrounding San Clemente Island over sandy bottom.

The potential for an explosion to injure or destroy vegetation would depend on the amount of vegetation present, the number of munitions used, and their net explosive weight. In areas where vegetation and locations for explosions overlap, vegetation on the surface of the water, in the water column, or rooted in the seafloor may be impacted.

Single-celled algae may overlap with underwater and sea surface explosion locations. If single-celled algae are in the immediate vicinity of an explosion, only a small number of individuals are likely to be impacted relative to their total population level. Additionally, the extremely fast growth rate and ubiquitous distribution of phytoplankton (Caceres et al., 2013; Levinton, 2013) suggest no meaningful impact on the resource. The low number of explosions relative to the amount of single-celled algae in the Study Area also decreases the potential for impacts on these vegetation types. Based on these factors, the impact on these types of vegetation would not be detectable and they are not discussed further in this section.

Macroalgae and marine vascular plants that are attached to the seafloor may occur in locations where explosions are conducted and may be adversely impacted for different reasons. Much of the attached macroalgae grows on live hard bottom that would be mostly protected in accordance with Navy mitigation measures. Procedural mitigation occurs for explosive activities to observe for floating vegetation prior to commencing firing or an explosive detonation until the floating vegetation is clear from the mitigation zone. For mitigation, the term "floating vegetation" refers specifically to floating concentrations of detached kelp paddies and Sargassum. Many of these activities will not occur in seafloor resource mitigation areas, which would benefit vegetation that occurs there.

Attached macroalgae grow quickly and are resilient through high levels of wave action (Mach et al., 2007), which may aid in their ability to withstand underwater explosions that occur near them. Attached macroalgae typically need hard or artificial substrate in order to grow. The potential distribution of attached macroalgae can be inferred by the presence of hard or artificial substrate that occurs at depths of less than 200 m throughout the Study Area. See Section 3.5 (Habitats) for information regarding the distribution of hard substrate in the Study Area. If attached macroalgae are in the immediate vicinity of an explosion, only a small number of them are likely to be impacted relative to their total population level. Only explosions occurring on or at shallow depth beneath the surface have the potential to impact floating macroalgae. Sea surface or underwater explosions could uproot or damage marine vascular plants if activities overlap with areas where they are rooted.

The potential for marine vascular plants (seagrass and eelgrass) to be impacted by underwater and surface explosions is unlikely as seagrass and eelgrass do not overlap with explosives training areas. Eelgrass are much less resilient to disturbance than marine algae; regrowth after uprooting can take up to 10 years (Dawes et al., 1997). Explosions may also temporarily increase the turbidity (sediment suspended in the water) of nearby waters, but the sediment would settle to pre-explosion conditions within a number of days. Sustained high levels of turbidity may reduce the amount of light that reaches vegetation. This scenario is not likely because seagrass and eelgrass do not overlap with explosives training areas.

3.3.3.2.1.1 Impacts from Explosives Under Alternative 1

Impacts from Explosives Under Alternative 1 for Training Activities

Impacts on algae near the surface would be localized and temporary as discussed above and are unlikely to affect the abundance, distribution, or productivity of vegetation. As discussed above, the depths, substrates, and relatively small areas of explosive footprints in comparison to vegetation distributions and total habitat areas in the Study Area indicate relatively little overlap between explosive footprints and the distribution of attached macroalgae and marine vascular plants. Furthermore, the majority of explosions take place in soft bottom habitats as described in Section 3.5 (Habitats). As a result, explosions would have (if any) localized, temporary impacts consisting of damage to or the removal of individuals and relatively small patches of vegetation. Vegetation is expected to regrow or recolonize the open patches created by explosives within a fairly short time (less than one year), resulting in no long-term effects on the productivity or distribution of attached macroalgae or marine vascular plants.

Impacts from Explosives Under Alternative 1 for Testing Activities

Impacts on algae near the surface would be localized and temporary as discussed above and are unlikely to affect the abundance, distribution, or productivity of vegetation. As discussed above, the depths, substrates, and relatively small areas of explosive footprints in comparison to vegetation distributions and total habitat areas in the Study Area indicate relatively little overlap between explosive footprints and the distribution of attached macroalgae and marine vascular plants. Furthermore, the majority of explosions take place in the open ocean or in soft bottom habitats as described in Section 3.5 (Habitats). As a result, explosions would have (if any) localized, temporary impacts consisting of damage to or the removal of individuals and relatively small patches of vegetation. Vegetation is expected to regrow or recolonize the open patches created by explosives within a fairly short time, resulting in no long-term effects on the productivity or distribution of attached macroalgae or marine vascular plants.

3.3.3.2.1.2 Impacts from Explosives Under Alternative 2

Impacts from Explosives Under Alternative 2 for Training Activities

Although activities under Alternative 2 occur at a higher rate and frequency relative to Alternative 1, impacts experienced by individuals or populations from explosives under Alternative 2 are not expected to be meaningfully different from those described under Alternative 1. Therefore, impacts associated with training activities under Alternative 2 are the same as Alternative 1.

Impacts from Explosives Under Alternative 2 for Testing Activities

Although activities under Alternative 2 occur at a higher rate and frequency relative to Alternative 1, physical disturbance and strike impacts experienced by individuals or populations from explosives under Alternative 2 are not expected to be meaningfully different from those described under Alternative 1. Therefore, impacts associated with testing activities under Alternative 2 are the same as Alternative 1.

3.3.3.2.1.3 Impacts from Explosives Under the No Action Alternative

Impacts from Explosives Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various explosive stressors would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.3.3.3 Energy Stressors

Energy stressors include electromagnetic devices, lasers, and radar; their use and physical effects are described in Section 3.0.3.3.3 (Energy Stressors). Although marine vascular plants are known to respond to magnetic field variations, effects on plant growth and development are not well understood (Maffei, 2014). The area of potential effects from electromagnetic devices or lasers is so small (limited to a few meters from source), and temporary, as to be discountable in terms of any effect on vegetation. Radar, which is high-frequency electromagnetic radiation, is not known to affect marine vascular plants, and is rapidly absorbed and does not propagate more than a few feet under water; again, the potential for an effect on vegetation is discountable. Therefore, energy stressors will have no impact on vegetation and will not be analyzed further in this section.

3.3.3.4 Physical Disturbance and Strike Stressors

This section analyzes the potential impacts on vegetation of the various types of physical disturbance and strike stressors that may occur during Navy training and testing activities within the Study Area. For a list of Navy activities that involve these stressors refer to Section 3.0.3.3.4 (Physical Disturbance and Strike Stressors). The physical disturbance and strike stressors that may impact marine vegetation include (1) vessels, (2) in-water devices, (3) military expended materials, and (4) seafloor devices.

The evaluation of the impacts from physical strike and disturbance stressors on vegetation focuses on proposed activities that may cause vegetation to be damaged by an object that is moving through the water (e.g., vessels and in-water devices), dropped into the water (e.g., military expended materials), or deployed on the seafloor (e.g., mine shapes and anchors). Not all activities are proposed throughout the Study Area. Wherever appropriate, specific geographic areas of potential impact are identified.

Single-celled algae may overlap with physical disturbance or strike stressors, but the impact would be minimal relative to their total population level and extremely high growth rates (Caceres et al., 2013); therefore, they will not be discussed further in this section. Marine vascular plants and macroalgae on the seafloor and on the sea surface are the only types of vegetation that occur in locations where physical disturbance or strike stressors may be encountered. Therefore, only marine vascular plants and macroalgae are analyzed further for potential impacts from physical disturbance or strike stressors.

3.3.3.4.1 Impacts from Vessels and In-Water Devices

Several different types of vessels (ships, submarines, boats, amphibious vehicles) and in-water devices (e.g., towed devices, unmanned underwater vehicles) are used during training and testing activities throughout the Study Area, as described in Chapter 2 (Description of Proposed Action and Alternatives). Vessel and in water device movements occur intermittently, are variable in duration (ranging from a few hours to a few weeks), and are dispersed throughout the Study Area. Events involving large vessels are widely spread over offshore areas, while smaller vessels are more active in nearshore areas.

The potential impacts from Navy vessels and in-water devices used during training and testing activities on vegetation are based on the vertical distribution of the vegetation. Vessels and in-water devices may impact vegetation by striking or disturbing vegetation on the sea surface or seafloor (Spalding et al., 2003). In the open ocean, marine algae on the sea surface such as kelp paddies have a patchy distribution. Marine algae could be temporarily disturbed if struck by moving vessels or by the propeller action of transiting vessels. These strikes could also injure the organisms that inhabit kelp paddies or other marine algal mat, such as sea turtles, seabirds, marine invertebrates, and fish. Marine algae are resilient to winds, waves, and severe weather that could sink the mat or break it into pieces. Impacts on marine algae by strikes may collapse the pneumatocysts (air sacs) that keep the mats afloat. Evidence suggests that some floating marine algae will continue to float even when up to 80 percent of the pneumatocysts are removed (Zaitsev, 1971).

Vegetation on the seafloor, such as marine vascular plants and macroalgae, may be disturbed by amphibious combat vehicles, and manned and unmanned underwater vehicles. Seagrasses are resilient to the lower levels of wave action that occur in sheltered estuarine shorelines, but are susceptible to vessel propeller scarring (Sargent et al., 1995). Seagrasses could take up to 10 years to fully regrow and recover from propeller scars (Dawes et al., 1997). Seafloor macroalgae may be present in locations where these vessels occur, but the impacts would be minimal because of their resilience, distribution, and biomass. Because seafloor macroalgae in coastal areas are adapted to natural disturbances, such as storms and wave action that can exceed 32.8 ft. (10 m) per second (Mach et al., 2007), macroalgae will quickly recover from vessel movements. Macroalgae that is floating in the area may be disturbed by amphibious combat vehicle activities, but the impact would not be detectable because of the small amount of macroalgae in areas where these activities occur and will not be considered further in this section.

Towed in-water devices include towed targets that are used during activities such as missile exercises and gun exercises. These devices are operated at low speeds either on the sea surface or below it. The analysis of in-water devices will focus on towed surface targets because of the potential for impacts on marine algae.

Unmanned underwater vehicles and autonomous underwater vehicles are used in training and testing activities in the Study Area. They are typically propeller driven and operate within the water column or crawl along the seafloor. The propellers of these devices are typically encased, eliminating the potential for seagrass propeller scarring. Although algae on the seafloor could be disturbed by these devices, unmanned underwater vehicles are not expected to compromise the health or condition of algae for the same reasons given for vessel disturbance.

Estimates of relative vessel and in-water device use and location for each alternative are provided in Section 3.0.3.3.4.1 (Vessels and In-Water Devices). These estimates are based on the number of activities predicted for each alternative. While these estimates provide a prediction of use, actual Navy vessel use depends upon military training requirements, deployment schedules, annual budgets, and other unpredictable factors. Testing and training concentrations are most dependent upon locations of Navy shore installations and established testing and training areas.

3.3.3.4.1.1 Impacts from Vessels and In-Water Devices Under Alternative 1

Impacts from Vessels and In-Water Devices Under Alternative 1 for Training Activities

Under Alternative 1, a variety of vessels and in-water device would be used throughout the Study Area during training activities, as described in Section 3.0.3.3.4.1 (Vessels and In-Water Devices). Most activities would involve one vessel or in-water device and may last from a few hours to two weeks, but activities may occasionally use two vessels or in-water devices. For this EIS/OEIS, more vessel traffic and in-water device use would occur in in the Southern California portion than the Hawaii portion of the Study Area (Table 3.0-16 and Table 3.0-18).

Because of the quantity of vessel traffic in Hawaiian nearshore waters since the 1940s (especially in waters off Oahu and within Pearl Harbor), it is thought that the existing vegetation community has shifted to dominance of species which are adapted to disturbance (Coles et al., 1997). In San Diego Bay, there are anticipated to be movements of Navy small boats, divers, and swimmers over eelgrass; otherwise eelgrass beds are avoided to the maximum practicable extent. Because of the dredging history of San Diego Bay near the Navy ship berths, it is anticipated that any nearby vegetation is accustomed to increased sedimentation and disturbance from these activities; therefore impacts from vessel movements on vegetation are expected to be similar and minimal (U.S. Department of the Navy, 2013).

In open ocean areas, vessel strikes of vegetation would be limited to floating marine algae. Vessel and in-water device movements may disperse or injure floating algal mats. Because algal distribution is patchy, mats may re-form, and events would be on a small spatial scale, Navy training activities involving vessel movement would not impact the general health of marine algae. Navy mitigation measures would ensure that vessels avoid large algal mats, such as detached kelp paddies or Sargassum, or other sensitive vegetation that other marine life depend on for food or habitat; these measures would safeguard this vegetation type from vessel strikes. This Standard Operating Procedure for vessels is "Watch personnel monitor their assigned sectors for any indication of danger to the ship and the personnel on board, such as a floating or partially submerged object or piece of debris, periscope, surfaced submarine, wisp of smoke, flash of light, or surface disturbance." In addition, as a standard collision avoidance procedure, prior to deploying a towed in-water device from a manned platform, the Navy searches the intended path of the device for any floating debris, objects, or animals (e.g., driftwood, concentrations of floating vegetation, marine mammals) that have the potential to obstruct or damage the device. This standard operating procedure benefits marine mammals, sea turtles, and vegetation through a reduction in the potential for physical disturbance and strike by a towed in-water device.

Under Alternative 1, the impacts from vessels during training activities would be minimal disturbances of algal mats and macroalgae. Eelgrass beds and kelp forests would be avoided to the maximum practicable extent. As such, eelgrass bed damage is not likely but, if it occurs, the impacts would be minor, such as damage from turbidity increases (Moore et al., 1996).

The net impact of vessels and in-water devices on vegetation is expected to be negligible under Alternative 1, based on (1) the quick recovery of most vegetation types; (2) the short-term nature of most vessel movements and local disturbances of the surface water, with some temporary increase in suspended sediment in shallow areas; and (3) the deployment of in-water devices at depths where they would not likely come in contact with vegetation.

Impacts from Vessels and In-Water Devices Under Alternative 1 for Testing Activities

Under Alternative 1, the Navy would use a variety of vessels in testing activities. Most of the testing activities involving vessel movements occur at sea within the Hawaii Range Complex and Southern California Range Complex, or within the transit corridor between the two range complexes. Some of the testing occurs pierside in Pearl Harbor or San Diego Bay and therefore would not generate these impacts.

On the sea surface, vessel strikes of vegetation would be limited to floating marine algae. Vessel movements may disperse or injure algae. However, algae may re-form, and testing events would be on a small spatial scale. Therefore, Navy testing activities involving vessel movement are not expected to impact the general health of marine algae. Eelgrass beds and kelp forests would be avoided to the maximum extent practicable and damage from testing is not likely but, if it occurs, the impacts would be minor, such as damage from short-term turbidity increases.

The net impact of vessel physical disturbances and strikes on vegetation during testing activities is expected to be negligible under Alternative 1, based on (1) the quick recovery of most vegetation types; (2) the short-term nature of most vessel movements and local disturbances of the surface water, with some temporary increase in suspended sediment in shallow areas, and (3) the deployment of in-water devices at depths where they would not likely come in contact with vegetation.

3.3.3.4.1.2 Impacts from Vessels and In-Water Devices Under Alternative 2

Impacts from Vessels and In-Water Devices Under Alternative 2 for Training Activities

Under Alternative 2, potential impacts on vegetation resulting from vessels and in-water devices associated with training activities would be similar to those discussed for activities under Alternative 1. There would be a very small increase in vessel and in-water device use in the Study Area. However, the difference would not result in substantive changes to the potential for or types of impacts on vegetation. Refer to Section 3.3.3.4.1.1 (Impacts from Vessels and In-Water Devices Under Alternative 1) for a discussion of potential impacts.

Impacts from Vessels and In-Water Devices Under Alternative 2 for Testing Activities

Under Alternative 2, potential impacts on vegetation resulting from vessels and in-water devices associated with testing activities would be similar to those discussed for activities under Alternative 1. Vessel use would increase by a small amount, while the number of activities involving in-water devices would remain the same. However, the difference in vessel use would not result in substantive changes to the potential for or types of impacts on vegetation. Refer to Section 3.3.3.4.1.1 (Impacts from Vessels and In-Water Devices Under Alternative 1) for a discussion of potential impacts.

3.3.3.4.1.3 Impacts from Vessels and In-Water Devices Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various physical disturbance and strike stressors (e.g., vessels and in-water devices) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.3.3.4.2 Impacts from Aircraft and Aerial Targets

Aircraft and aerial target stressors are not applicable to vegetation and will not be analyzed further in this section.

3.3.3.4.3 Impacts from Military Expended Materials

This section analyzes the strike potential to vegetation of the following categories of military expended materials: (1) all sizes of non-explosive practice munitions; (2) fragments of high-explosive munitions; (3) expended targets; and (4) expended materials other than munitions, such as sonobuoys and miscellaneous accessories (e.g., canisters, endcaps, pistons). See Appendix F (Military Expended Material and Direct Strike Impact Analyses) for further details on the disturbance footprint for military expended materials on bottom habitat.

Military expended materials can impact macroalgae and marine vascular plants in coastal areas. Many types of military expended materials are deployed in the open ocean. In coastal water training areas, only projectiles (small and medium), target fragments, and countermeasures could be introduced into areas where shallow water vegetation may be impacted.

The potential for impacts on marine vegetation from military expended materials would depend on the presence and amount of vegetation, and number of military expended materials. Most deposition of military expended materials occurs within the confines of established training and testing areas. These areas are largely away from the coastline, and the potential for impacts on vegetation is low.

Military expended materials can potentially impact marine vascular plants on the seafloor by disturbing, crushing, or shading, which may interfere with photosynthesis. In the event that a marine vascular plant is not able to photosynthesize, its ability to produce energy is compromised. However, the intersection of marine vascular plants and military expended materials is limited. Marine vascular plants generally grow in waters that are sheltered from wave action such as estuaries, lagoons, and bays (Phillips & Meñez, 1988). Locations for the majority of Navy training and testing activities where military materials are expended do not provide this type of habitat. The potential for detectable impacts on marine vascular plants from expended materials would be based on their size or low density (e.g., small projectiles, small decelerators/parachutes, endcaps, and pistons) of the majority of the materials that could be used in or drift into these areas from offshore. Larger, denser materials, such as non-explosive practice munitions and sonobuoys would be used farther offshore and are likely to sink rapidly where they land. Falling materials could cause bottom sediments to be suspended. Resuspension of the sediment could impact water quality and decrease light exposure, but since it would be short-term (hours), stressors from military expended materials would not likely impact the general health of marine vascular plants.

The following are descriptions of the types of military expended materials that could impact marine algae and marine vascular plants. Marine algae could overlap with military expended materials anywhere in the Study Area; however, the Silver Strand Training Complex is the only location in the Study Area where these materials could overlap with marine vascular plants.

Small-, Medium-, and Large-Caliber Projectiles. Small-, medium-, and large-caliber non-explosive practice munitions, or fragments of high-explosive projectiles, expended during training and testing activities rapidly sink to the seafloor. The majority of these projectiles would be expended in the open ocean areas of Hawaii and southern California Range Complexes. Because of the small sizes of the projectiles and their casings, damage to marine vegetation is unlikely. Large-caliber projectiles are primarily used in offshore areas at depths greater than 85 ft., while small- and medium-caliber projectiles may be expended in both offshore and coastal areas (at depths mostly less than 85 ft.) within special use airspace in the Southern California Range Complex Warning Area 291 (W-291 [see Figure 2.1-6]) and at selected areas on San Clemente Island. Marine algae could occur where these materials are expended, but seagrasses generally do not because these activities do not normally occur in water that is shallow enough for seagrass to grow.

Bombs, Missiles, and Rockets. Bombs, missiles, and rockets, or their fragments (if high-explosive) are expended offshore (at depths mostly greater than 85 ft.) during training and testing activities, and rapidly sink to the seafloor. Marine algae could occur where these materials are expended. However, marine vascular plants generally would not occur where these materials are expended because these activities do not normally occur in water that is shallow enough for marine vascular plants to grow.

Decelerators/Parachutes. Decelerators/parachutes of varying sizes are used during training and testing activities. The types of activities that use decelerators/parachutes, the physical characteristics of these expended materials, where they are used, and the number of activities that would occur under each alternative are discussed in Section 3.0.3.3.5 (Entanglement Stressors). Kelp, other marine algae, and marine vascular plants could occur where these materials are expended.

Targets. Many training and testing activities use targets. Targets that are hit by munitions could break into fragments. Target fragments vary in size and type, but most fragments are expected to sink. Pieces of targets that are designed to float are recovered when practical. Target fragments would be spread out over large areas. Marine algae could occur where these materials are expended.

Countermeasures. Defensive countermeasures (e.g., chaff, flares, and acoustic devices) are used to protect against incoming weapons (e.g., missiles). Chaff is made of aluminum-coated glass fibers, and flares are pyrotechnic devices. Chaff, chaff canisters, and flare end caps are expended materials. Chaff and flares are dispensed from aircraft or fired from ships. Floating marine algal mats could occur in any of the locations that these materials are expended.

3.3.3.4.3.1 Impacts from Military Expended Materials Under Alternative 1

<u>Impacts from Military Expended Materials under Alternative 1 for Training Activities</u>

Depending on the size and type or composition of the expended materials and where they happen to strike vegetation, individuals could be killed, fragmented, covered, buried, sunk, or redistributed. This type of disturbance would not likely differ from conditions created by waves or rough weather. If enough military expended materials land on algal mats, the mats can sink. The likelihood is low that mats would accumulate enough material to cause sinking from military activities, as military expended materials are dispersed widely through an activity area. The few algal mats that would prematurely sink would not have an impact on populations. Strikes would have little impact, and would not likely result in the mortality of floating algal mats or other algae, although these strikes may injure the organisms that inhabit marine algal mats, such as sea turtles, birds, and marine invertebrates.

Military expended materials used for training activities are not expected to pose a risk to marine algae or marine vascular plants because (1) the relative coverage of marine algae in the Study Area is low, (2) the impact area of military expended materials is very small relative to marine algae distribution, and (3) marine vascular plants overlap with areas where the stressor occurrence is very limited**.** The Navy will also implement procedural mitigation for non-explosive activities to observe for floating vegetation prior to commencing firing, until the floating vegetation is clear from the mitigation zone. If floating vegetation is observed prior to the initial start of an activity, the activity will either be relocated to an area where floating vegetation is not observed in concentrations, or the initial start of the activity will be ceased until the mitigation zone is clear of floating vegetation concentrations (see Section 5.2.1, Procedural Mitigation Development). Based on these factors, potential impacts on marine algae and marine vascular plants from military expended materials are not expected to result in detectable changes in the growth, survival, or propagation of individuals, and are not expected to result in population-level impacts.

Impacts from Military Expended Materials Under Alternative 1 for Testing Activities

Testing activities under Alternative 1 would include military expended materials that would typically be of the same type listed under training activities.

Depending on the size and type or composition of the expended materials and where they happen to strike vegetation, individuals could be killed, fragmented, covered, buried, sunk, or redistributed. This type of disturbance would not likely differ from conditions created by waves or rough weather. If enough military expended materials land on algal mats, the mats can sink. The likelihood is low that mats would accumulate enough material to be sunk by military activities, as military expended materials are dispersed widely through an activity area. The few algal mats that would prematurely sink would not have an impact on populations. Strikes would have little impact, and would not likely result in the mortality of floating algal mats or other algae, although these strikes may injure the organisms that inhabit marine algal mats, such as sea turtles, birds, and marine invertebrates.

Military expended materials used for testing activities are not expected to pose a risk to marine algae or marine vascular plants because (1) the relative coverage of marine algae in the Study Area is low, (2) the impact area of military expended materials is very small relative to marine algae distribution, and (3) marine vascular plants overlap with areas where the stressor occurrence is very limited. Based on these factors, potential impacts on marine algae and marine vascular plants from military expended materials are not expected to result in detectable changes in the growth, survival, or propagation of individuals, and are not expected to result in population-level impacts.

3.3.3.4.3.2 Impacts from Military Expended Materials Under Alternative 2

Impacts from Military Expended Materials Under Alternative 2 for Training Activities

The locations of training activities using military expendable materials would be the same under Alternatives 1 and 2. The total area affected for all training activities combined would increase by less than 15 ac. under Alternative 2, and therefore the potential impacts would be similar between the two alternatives. Refer to Section 3.3.3.4.3 (Impacts from Military Expended Materials) for a discussion of impacts on vegetation.

Impacts from Military Expended Materials Under Alternative 2 for Testing Activities

The locations of testing activities using military expendable materials would be the same under Alternatives 1 and 2. The total area affected for all testing activities combined would increase by less than 14 ac. under Alternative 2, and therefore the potential impacts would be similar between the two alternatives. Refer to Section 3.3.3.4.3 (Impacts from Military Expended Materials) for a discussion of impacts on vegetation.

Impacts from Military Expended Materials Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various physical disturbance and strike stressors (e.g., military expended materials) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.3.3.4.4 Impacts from Seafloor Devices

For a discussion of the types of activities that use seafloor devices see Appendix B (Activity Stressor Matrices). For a discussion of where they are used, and how many activities would occur in the Study Area, see Section 3.0.3.3.4.3 (Seafloor Devices). Vegetation on the seafloor may be impacted by seafloor devices, while vegetation on the sea surface such as marine algal mats is not likely to be impacted; therefore, it will not be discussed further in this section. Marine vascular plants and seafloor macroalgae in the Study Area may be impacted by the use of seafloor devices.

Seafloor device operation, installation, or removal could impact marine vascular plants by physically removing vegetation (e.g., uprooting), crushing vegetation, temporarily increasing the turbidity (sediment suspended in the water) of waters nearby, or shading, which may interfere with photosynthesis. If marine vascular plants are not able to photosynthesize, their ability to produce energy is compromised. However, the intersection of marine vascular plants and seafloor devices is limited, and suspended sediments would settle in a few hours. Precision anchoring would not occur in seafloor resource mitigation areas (except in designated locations), which would benefit vegetation that occurs there.

3.3.3.4.4.1 Impacts from Seafloor Devices Under Alternative 1

Impacts from Seafloor Devices Under Alternative 1 for Training Activities

Under Alternative 1, seafloor devices would be used throughout the Study Area during training activities, as described in Chapter 2 (Description of Proposed Action and Alternatives). Most seafloor device use would occur in the southern California portion of the Study Area. The Navy uses sandy substrates devoid of marine vegetation to the extent practicable. Marine plant species found within the relatively shallow waters of the Study Area are adapted to natural disturbance and recover quickly from storms, as well as from wave and surge action. Bayside marine plant species, such as eelgrass, are found in areas where wave action is minimal. Installation of seafloor devices may impact vegetation in benthic habitats, but the impacts would be temporary and would be followed by rapid (i.e., within a few weeks) recovery, particularly in oceanside boat lanes in nearshore waters off San Diego and in designated training areas adjoining San Clemente Island. Eelgrass beds show signs of recovery after a cessation of physical disturbance; the rate of recovery is a function of the severity of the disturbance (Neckles et al., 2005). The main factors that contribute to eelgrass recovery include improving water quality and cessation of major disturbance activities (e.g., dredging) (Chavez, 2009). Seafloor devices, in contrast to dredging, have a minor impact that is limited to the area of the actual pile and footprint of the mooring.

Seafloor device installation in shallow water habitats under Alternative 1 training activities would pose a negligible risk to marine vegetation. Any damage from seafloor devices would be followed by a recovery period lasting weeks to months, depending on the species, but could take up to 10 years for certain seagrass species. Although marine vegetation growth near seafloor devices installed during training activities under Alternative 1 would be inhibited during recovery, population-level impacts are unlikely because of the small, local impact areas; the frequency of training activities; and the wider geographic distribution of seagrasses in and adjacent to training areas.

Impacts from Seafloor Devices Under Alternative 1 for Testing Activities

Under Alternative 1, seafloor devices would be used throughout the Study Area during testing activities, as described in Chapter 2 (Description of Proposed Action and Alternatives). The Navy uses sandy substrates devoid of marine vegetation to the extent practicable. Most seafloor device use would occur in the southern California portion of the Study Area. Marine plant species found within Hawaii Range Complex, San Diego Bay, and in waters off San Clemente Island are adapted to natural disturbance and recover quickly from storms, as well as from high-energy wave action and tidal surges in oceanside areas. As noted previously, eelgrass beds would require longer recovery periods in bayside areas.

Seafloor devices installed in shallow-water habitats during Alternative 1 testing activities would pose a negligible risk to marine vegetation. Any damage from seafloor devices would be followed by a recovery period lasting weeks to months, depending on the species, but could take up to 10 years for certain seagrass species. Although marine vegetation growth near seafloor devices installed during testing activities under Alternative 1 would be inhibited during recovery, population-level impacts are unlikely because of the small, local impact areas; the frequency of training activities; and the wider geographic distribution of seagrasses in and adjacent to testing areas.

3.3.3.4.4.2 Impacts from Seafloor Devices Under Alternative 2

Impacts from Seafloor Devices Under Alternative 2 for Training Activities

The locations and types of training activities using seafloor devices would be the same under Alternatives 1 and 2. There would be a very small increase in the number of activities conducted in the Southern California Range Complex. However, the increase would not result in substantive changes to the potential for or types of impacts on vegetation. Refer to Section 3.3.3.4.4.1 (Impacts from Seafloor Devices Under Alternative 1) for a discussion of impacts on vegetation.

Impacts from Seafloor Devices Under Alternative 2 for Testing Activities

The locations and types of testing activities using seafloor devices would be the same under Alternatives 1 and 2. There would be a very small increase in the number of activities conducted in the Southern California Range Complex. However, the increase would not result in substantive changes to the potential for or types of impacts on vegetation. Refer to Section 3.3.3.4.4.1 (Impacts from Seafloor Devices Under Alternative 1) for a discussion of impacts on vegetation.

3.3.3.4.4.3 Impacts from Seafloor Devices Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various physical disturbance and strike stressors (e.g., seafloor devices) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.3.3.4.5 Impacts from Pile Driving

For a discussion of pile driving, including where they are used and how many activities would occur in the Study Area, see Section 3.0.3.3.1.3 (Pile Driving). Pile driving would not impact vegetation on the sea surface, such as marine algal mats; therefore, floating vegetation will not be discussed further in this section. Pile driving could occur in sandy shallow water coastal areas at Silver Strand Training Complex and at Camp Pendleton, both of which are in the Southern California Range Complex and not in the Hawaii Range Complex.

Pile driving may, however, impact marine vascular plants and seafloor macroalgae in the Study Area. Pile driving could impact marine vascular plants and seafloor macroalgae by physically removing vegetation (e.g., uprooting), crushing vegetation, temporarily increasing the turbidity (sediment suspended in the water) of waters nearby, or shading, which may interfere with photosynthesis. If vegetation is not able to photosynthesize, its ability to produce energy is compromised. However, the intersection of marine macroalgae and marine vascular plants and pile driving is limited, and any suspended sediments would settle in a few days.

In bay areas, recovery of marine vascular plants such as eelgrass from direct disturbance by pile driving would occur over longer timeframes. Eelgrass beds show signs of recovery after a cessation of physical disturbance; the rate of recovery is a function of the severity of the disturbance (Neckles et al., 2005). The main factors that contribute to eelgrass recovery include improving water quality and cessation of major disturbance activities (e.g., dredging) (Chavez, 2009). Pile driving, in contrast to dredging, has a minor impact that is limited to the area of the actual pile and footprint of the mooring.

3.3.3.4.5.1 Impacts from Pile Driving Under Alternative 1

Impacts from Pile Driving Under Alternative 1 for Training Activities

Pile driving may impact vegetation in benthic habitats, but the impacts would be temporary and would be followed by rapid (i.e., within a few weeks) recovery, particularly in oceanside boat lanes in nearshore waters off San Diego, which are mainly sandy bottoms with limited or no benthic vegetation. However, opportunistic and potentially invasive vegetation could become established in disturbed areas. Pile driving in shallow water habitats under Alternative 1 training activities would pose a negligible risk to marine vegetation. Any damage from seafloor devices would be followed by a recovery period lasting weeks to months, depending on the species, but could take up to 10 years for certain marine vascular plant species. Although marine vegetation growth near seafloor devices installed during training activities under Alternative 1 would be inhibited, population-level impacts are unlikely because of the small, local impact areas; the frequency of training activities; and the wider geographic distribution of marine vegetation in and adjacent to training areas.

Impacts from Pile Driving Under Alternative 1 for Testing Activities

There would be no pile driving or removal associated with testing activities. Therefore, pile driving is not analyzed in this subsection.

3.3.3.4.5.2 Impacts from Pile Driving Under Alternative 2

Impacts from Pile Driving Under Alternative 2 for Training Activities

The locations, number of training events, and potential effects associated with pile driving and removal would be the same under Alternatives 1 and 2. Refer to Section 3.3.3.4.5.1 (Impacts from Pile Driving Under Alternative 1) for a discussion of impacts on vegetation.

Impacts from Pile Driving Under Alternative 2 for Testing Activities

There would be no pile driving or removal associated with testing activities. Therefore, pile driving is not analyzed in this subsection.

3.3.3.4.5.3 Impacts from Pile Driving Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various physical disturbance and strike stressors (e.g., pile driving) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.3.3.5 Entanglement Stressors

Entanglement stressors associated with Navy training and testing activities are described in Section 3.0.3.3.5 (Entanglement Stressors). Expended materials that have the potential to cause entanglement generally sink to the bottom or drift ashore, and thereby could come into contact with macroalgae or marine vascular plants, possibly abrading or breaking individuals, but such effects would be isolated, very small in scale, and temporary as the vegetation would regrow. No effects on the productivity or distribution of vegetation are anticipated.

3.3.3.6 Ingestion Stressors

Ingestion stressors associated with Navy training and testing activities are described in Section 3.0.3.3.6 (Ingestion Stressors). Ingestion stressors will not impact vegetation due to the photosynthetic nature of vegetation.

3.3.3.7 Secondary Stressors

This section analyzes potential impacts on marine vegetation exposed to stressors indirectly through impacts on habitat and prey availability.

3.3.3.7.1 Impacts on Habitat

Section 3.2 (Sediments and Water Quality) and Section 3.5 (Habitats) consider the impacts on marine sediments and water quality and abiotic habitats from explosives and explosion byproducts, metals, chemicals other than explosives, and other materials (marine markers, flares, chaff, targets, and miscellaneous components of other materials). One example from the sediment and water quality analysis of a local impact on water quality could be an increase in cyanobacteria associated with munitions deposits in marine sediments. Cyanobacteria may proliferate when iron is introduced to the marine environment, and this proliferation can affect adjacent habitats by releasing toxins and can create hypoxic conditions. Introducing iron into the marine environment from munitions or infrastructure is not known to cause toxic red tide events; rather, these harmful events are more associated with natural causes (e.g., upwelling) and the effects of other human activities (e.g., agricultural runoff and other coastal pollution) (Hayes et al., 2007). High-order explosions consume most of the explosive material, leaving only small or residual amounts of explosives and combustion products. Many combustion products are common seawater constituents. All combustion products are rapidly diluted by ocean currents and circulation (see Section 3.2.3.1, Explosives and Explosives Byproducts). Explosives byproducts from high-order detonations present no indirect stressors to marine vegetation through sediment or water.

The analysis included in Section 3.2 (Sediments and Water Quality) determined that neither state nor federal standards or guidelines for sediments or water quality would be violated by the No Action Alternative, Alternative 1, or Alternative 2. Because standards for sediment and water quality would not be violated, population-level impacts on marine vegetation are not likely to be detectable and are therefore inconsequential. Therefore, because these standards and guidelines are structured to protect human health and the environment, and the proposed activities do not violate them, no indirect impacts are anticipated on vegetation from the training and testing activities proposed by the No Action Alternative, Alternative 1, or Alternative 2.

Other materials that are re-mobilized after their initial contact with the seafloor (e.g., by waves or currents) may continue to strike or abrade marine vegetation. Secondary physical strike and disturbances are relatively unlikely because most expended materials are denser than the surrounding sediments (e.g., metal) and are likely to remain in place as the surrounding sediment moves. Potential secondary physical strike and disturbance impacts may cease when (1) the military expended material is too massive to be mobilized by typical oceanographic processes, (2) the military expended material becomes encrusted by natural processes and incorporated into the seafloor, or (3) the military expended material becomes permanently buried. Although individual organisms could be impacted by secondary physical strikes, the viability of populations or species would not be impacted.

3.3.3.7.2 Impacts on Prey Availability

Prey availability as a stressor is not applicable to vegetation and will not be analyzed further in this section.

Therefore, based on the information provided in these subsections, secondary stressors would not have an impact on vegetation.

3.3.4 Summary of Potential Impacts on Vegetation

Activities described in this EIS/OEIS that have potential impacts on vegetation are widely dispersed, and not all stressors would occur simultaneously in a given location. The stressors that have potential impacts on marine vegetation include explosions, physical disturbances or strikes (vessels and in-water devices, military expended materials, seafloor devices), and secondary. Unlike mobile organisms, vegetation cannot flee from stressors once exposed. Marine algae are the most likely to be exposed to multiple stressors in combination because they occur over large expanses. Discrete locations in the Study Area (mainly within offshore areas with depths greater than 82 ft. in portions of range complexes and testing ranges) could experience higher levels of activity involving multiple stressors, which could result in a higher potential risk for impacts on marine algae.

3.3.4.1 Combined Impacts of All Stressors Under Alternative 1

The potential for exposure of marine vegetation to multiple stressors would be limited because activities are not concentrated in coastal distributions (areas with depths less than 82 ft.) of these species. The combined impacts under Alternative 1 of all stressors would not be expected to affect marine vegetation populations because (1) activities involving more than one stressor are generally short in duration, (2) such activities are dispersed throughout the Study Area, (3) activities are generally scheduled where previous activities have occurred, and (4) the large resilient populations present in the Study Area. The aggregate effect on marine vegetation would not observably differ from existing conditions.

3.3.4.2 Combined Impacts of All Stressors Under Alternative 2

Under Alternative 2 the potential for exposure of seagrasses and attached macroalgae to multiple stressors would limited, because activities are not concentrated in coastal distributions (areas with depths less than 82 ft.) of these species. The combined impacts under Alternative 2 of all stressors would not be expected to affect marine vegetation populations because (1) activities involving more than one stressor are generally short in duration, (2) such activities are dispersed throughout the Study Area, (3) activities are generally scheduled where previous activities have occurred, and (4) the large resilient populations present in the Study Area. The aggregate effect on marine vegetation would not observably differ from existing conditions.

3.3.4.3 Combined Impacts of All Stressors Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various stressors would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.3.5 Endangered Species Act Determinations

There are no species of vegetation listed as endangered, threatened, candidate, or proposed under the ESA in the Study Area.

REFERENCES

Allen, J. A. (1998). Mangroves as alien species: The case of Hawaii. *Global Ecology and Biogeography Letters, 7*(1), 61–71.

Arnold, T., C. Mealey, H. Leahey, A. W. Miller, J. M. Hall-Spencer, M. Milazzo, and K. Maers. (2012). Ocean acidification and the loss of phenolic substances in marine plants. *PLoS One, 7*(4), e35107–e35107.

Bouillon, S., V. H. Rivera-Monroy, R. R. Twilley, and J. G. Kairo. (2009). Mangroves. In D. D. A. Laffoley & G. Grimsditch (Eds.), *The Management of Natural Coastal Carbon Sinks*. Gland, Switzerland: International Union for the Conservation of Nature.

Buhl-Mortensen, L., A. Vanreusel, A. J. Gooday, L. A. Levin, I. G. Priede, P. Buhl-Mortensen, H. Gheerardyn, N. J. King, and M. Raes. (2010). Biological structures as a source of habitat heterogeneity and biodiversity on the deep ocean margins. *Marine Ecology, 31*(1), 21–50.

Byrnes, J. E., D. C. Reed, B. J. Cardinale, K. C. Cavanaugh, S. J. Holbrooks, and R. J. Schmitts. (2011). Climate-driven increases in storm frequency simplify kelp forest food webs. *Global Change Biology, 17*, 2513–2525.

Caceres, C., F. G. Taboada, J. Hofer, and R. Anadon. (2013). Phytoplankton Growth and Microzooplankton Grazing in the Subtropical Northeast Atlantic. *PLoS ONE, 8*(7).

Calflora. (2016). *Spartina alterniflora*. Retrieved from http://www.calflora.org/cgi-bin/species_query.cgi?where-calrecnum=7699.

California Invasive Plant Council. (2016). *Invasive Plants of California's Wildland: Spartina alterniflora*. Retrieved from http://www.cal-ipc.org/ip/management/ipcw/pages/detailreport.cfm@usernumber=75&surveynumber=182.php.

Castro, P., and M. E. Huber. (2000). Marine prokaryotes, protists, fungi, and plants. In: *Marine Biology* (3rd ed., pp. 83–103). New York, NY: McGraw-Hill.

Castro, P., and M. E. Huber. (2007). Chemical and physical features of seawater and the world ocean *Marine Biology* (6th ed., pp. 45–68). New York, NY: McGraw-Hill.

Center for Disease Control and Prevention. (2004). *Red Tide: Harmful Algal Blooms*. Retrieved from http://www.cdc.gov/hab/redtide/pdfs/about.pdf.

Chavez, E. (2009). *2008 San Diego Bay Eelgrass Inventory and Bathymetry Update*. San Diego, CA: San Diego Unified Port District Environmental Advisory Committee.

Cheroske, A. G., S. L. Williams, and R. C. Carpenter. (2000). Effects of physical and biological disturbances on algal turfs in Kaneohe Bay, Hawaii. *Journal of Experimental Marine Biology and Ecology, 248*, 1–34.

Chmura, G. L. (2009). Tidal Salt Marshes In D. D. A. Laffoley & G. Grimsditch (Eds.), *The Management of Natural Coastal Carbon Sinks* (pp. 5–11). Gland, Switzerland: International Union for the Conservation of Nature.

Coles, S. L., R. C. DeFelice, L. G. Eldredge, J. T. Carlton, R. L. Pyle, and A. Suzumoto. (1997). *Biodiversity of Marine Communities in Pearl Harbor, Oahu, Hawaii with Observations on Introduced Exotic Species* (Bishop Museum Technical Report No. 10). Honolulu, HI: Bishop Museum Press.

Cooper, D. A., and P. L. Corcoran. (2010). Effects of mechanical and chemical processes on the degradation of plastic beach debris on the island of Kauai, Hawaii. *Marine Pollution Bulletin, 60*, 650–654.

Culbertson, J. B., I. Valiela, M. Pickart, E. E. Peacock, and C. M. Reddy. (2008). Long-term consequences of residual petroleum on salt marsh grass. *Journal of Applied Ecology, 45*(4), 1284–1292.

Dameron, O. J., M. Parke, M. A. Albins, and R. Brainard. (2007). Marine debris accumulation in the Northwestern Hawaiian Islands: An examination of rates and processes. *Marine Pollution Bulletin 54*, 423–433.

Dawes, C. J., J. Andorfer, C. Rose, C. Uranowski, and N. Ehringer. (1997). Regrowth of the seagrass, *Thalassia testudinum,* into propeller scars. *Aquatic Botany, 59*(1–2), 139–155.

Dawes, C. J. (1998). *Marine Botany* (2nd ed.). New York, NY: John Wiley and Sons, Inc.

Dobroski, N., C. Brown, R. Nedelcheva, C. Scianni, and J. Thompson. (2015). *2015 Beinnial Report on the California Marine Invasive Species Program*. Sacramento, CA: California State Lands Commission Marine Facilities Division.

Doney, S. C., M. Ruckelshaus, D. J. Emmett, J. P. Barry, F. Chan, C. A. English, H. M. Galindo, J. M. Grebmeier, A. B. Hollowed, N. Knowlton, J. Polovina, N. N. Rabalais, W. J. Sydeman, and L. D. Talley. (2012). Climate change impacts on marine ecosystems. *Annual Review of Marine Science, 4*(1), 11–37.

Dreyer, G. D., and W. A. Niering. (1995). Tidal marshes of Long Island Sound: Ecology, history and restoration. *Connecticut Arboretum Bulletin, 34*(2), 1–45.

Fonseca, M. S., W. J. Kenworthy, and G. W. Thayer. (1998). *Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters*. (National Oceanic and Atmospheric Administration's Coastal Ocean Program Decision Analysis Series No. 12). Silver Spring, MD: National Oceanic and Atmospheric Administration, Coastal Ocean Office.

Gagnon, K., S. J. Peacock, Y. Jin, and M. A. Lewis. (2015). Modelling the spread of the invasive alga Codium fragile driven by long-distance dispersal of buoyant propagules. *Ecological Modelling, 316*, 111–121.

Garrison, T. (2004). Essentials of Oceanography (3rd ed.). Pacific Grove, CA: Brooks/Cole-Thomas Learning.

Giraudeau, J., and L. Beaufort. (2007). Coccolithophores: From Extant Populations to Fossil Assemblages *Developments in Marine Geology* (Vol. 1, pp. 409–439).

Global Invasive Species Database. (2005). *List of invasive marine algae in California*. Retrieved from http://www.issg.org/database/species/search.asp?sts=sss&st=sss&fr=1&sn=&rn=California&hci=8&ei=186&lang=EN&Image1.x=22&Image1.y=12.

Green, E. P., and F. T. Short. (2003). *World Atlas of Seagrasses*. Berkeley, CA: University of California Press.

Gregory, M. R. (2009). Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society of London, 364*, 2013–2025.

Grove, R., K. Zabloudil, T. Norall, and L. Deysher. (2002). Effects of El Niño events on natural kelp beds and artificial reefs in southern California. *ICES Journal of Marine Science, 59*, S330–S337.

Harley, C. D., A. R. Hughes, K. M. Hultgren, B. G. Miner, C. J. B. Sorte, C. S. Thomber, L. F. Rodriguez, T. L., and S. L. Williams. (2006). The impacts of climate change in coastal marine systems. *Ecology Letters, 9*, 228–242.

Hayes, M. O., R. Hoff, J. Michel, D. Scholz, and G. Shigenaka. (1992). *An Introduction to Coastal Habitats and Biological Resources for Oil Spill Response*. Seattle, WA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Hazardous Materials Response and Assessment Division.

Hayes, P. K., N. A. El Semary, and P. Sanchez-Baracaldo. (2007). The taxonomy of cyanobacteria: Molecular insights into a difficult problem. In J. Brodie & J. Lewis (Eds.), *Unravelling the Algae: The Past, Present, and Future of Algal Systematics* (pp. 93–102). Boca Raton, FL: CRC Press.

Hemminga, M. A., and C. M. Duarte. (2000). Seagrasses in the human environment *Seagrass Ecology* (pp. 248–291). Cambridge, United Kingdom: Cambridge University Press.

Hoff, R., P. Hensel, E. C. Proffitt, P. Delgado, G. Shigenaka, R. Yender, R. Hoff, and A. J. Mearns. (2002). *Oil Spills in Mangroves: Planning & Response Considerations*. Silver Spring, MD: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Ocean Service, Office of Response and Restoration.

Hughes, T. P., M. J. Rodrigues, D. R. Bellwood, D. Ceccarelli, O. Hoegh-Guldberg, L. McCook, N. Moltschaniwskyj, M. S. Pratchett, R. S. Steneck, and B. Willis. (2007). Phase shifts, herbivory, and the resilience of coral reefs to climate change. *Current Biology, 17*(4), 360–365.

Jones, C. L., T. W. Anderson, and M. S. Edwards. (2013). Evaluating eelgrass site quality by the settlement, performance, and survival of a marine fish. *Journal of Experimental Marine Biology and Ecology, 445*, 61–68.

Kaplanis, N. J., J. Harris, and J. Smith. (2016). Distribution patterns of the non-native seaweeds *Sargassum horneri* (Turner) C. Agardh and *Undaria pinnatifida* (Harvey) Suringar on the San Diego and Pacific coast of North America. *Aquatic Invasions, 11*(2), 111–124.

Keller, A. A., E. L. Fruh, M. M. Johnson, V. Simon, and C. McGourty. (2010). Distribution and abundance of anthropogenic marine debris along the shelf and slope of the US West Coast. *Marine Pollution Bulletin, 60*(5), 692–700.

Kenworthy, W. J., M. J. Durako, S. M. R. Fatemy, H. Valavi, and G. W. Thayer. (1993). Ecology of seagrasses in northeastern Saudi Arabia one year after the Gulf War oil spill. *Marine Pollution Bulletin, 27*, 213–222.

Kudela, R., W. Cochlan, and A. Roberts. (2004). Spatial and temporal patterns of *Pseudo-nitzschia* spp. in central California related to regional oceanography. In K. A. Steidinger, J. H. Landsberg, C. R. Tomas, & G. A. Vargo (Eds.), *Harmful Algae 2002* (pp. 347–349). St. Petersburg, FL: Florida Fish and Wildlife Conservation Commission, Florida Institute of Oceanography, and Intergovernmental Oceanographic Commission of UNESCO.

Kudela, R. M., and W. P. Cochlan. (2000). Nitrogen and carbon uptake kinetics and the influence of irradiance for a red tide bloom off southern California. *Aquatic Microbial Ecology, 21*, 31–47.

Laffoley, D., and G. Grimsditch. (2009). Introduction. In D. Laffoley & G. Grimsditch (Eds.), *The Management of Natural Coastal Carbon Sinks* (pp. 1–3). Gland, Switzerland: International Union for the Conservation of Nature.

Leet, W. S., C. M. Dewees, R. Klingbeil, and E. J. Larson. (2001). *California's Living Marine Resources: A Status Report*. Sacramento, CA: California Department of Fish and Game.

Lehmköster, J. (2015). Climate change impacts on marine ecosystems. In T. Schröder (Ed.), *World Ocean Review* (pp. 102–117). Hamburg, Germany: Mareverlag Publishing House.

Levinton, J. S. (2009). *Marine Biology: Function, Biodiversity, Ecology* (3rd ed.). New York, NY: Oxford University Press.

Levinton, J. S. (2013). Plankton *Marine Biology: Function, Biodiversity, Ecology* (4th ed., pp. 141–162). New York, NY: Oxford University Press.

Mach, K. J., B. B. Hale, M. W. Denny, and D. V. Nelson. (2007). Death by small forces: A fracture and fatigue analysis of wave-swept macroalgae. *The Journal of Experimental Biology, 210*(13), 2231–2243.

Maffei, M. E. (2014). Magnetic field effects on plant growth, development, and evolution. *Frontiers in Plant Science, 5*(445), 1–15.

Marine Corps Base Hawaii. (2011). *Marine Corps Base Hawaii Integrated Natural Resources Management Plan (MCB Hawaii INRMP) Update (2012–2016)*. Kailua, HI: Sustainable Resources Group International, Inc.

Marks, L. M., P. Salinas-Ruiz, D. C. Reed, S. J. Holbrook, C. S. Culver, J. M. Engle, G. J. Kushner, J. E. Caselle, J. Freiwald, J. P. Williams, J. R. Smith, L. E. Aguilar-Rosas, and N. J. Kaplanis. (2015). Range expansion of a non-native, invasive macroalga *Sargassum horneri* (Turner) C. Agardh, 1820 in the eastern Pacific. *BioInvasions Records, 4*(4), 243–248.

Martinez, B., F. Arenas, M. Rubal, S. Burgues, R. Esteban, I. Garcia-Plazaola, F. L. Figueroa, R. Pereira, L. Saldana, I. Sousa-Pinto, A. Trilla, and R. M. Viejo. (2012). Physical factors driving intertidal macroalgae distribution: Physiological stress of a dominant fucoid at its southern limit. *Oecologia, 170*(2), 341–353.

McCoy, K., A. Heenan, J. Asher, P. Ayotte, K. Gorospe, A. Gray, K. Lino, J. Zamzow, and I. Williams. (2016). *Ecological monitoring 2016—reef fishes and benthic habitats of the main Hawaiian Islands, Northwestern Hawaiian Islands, Pacific Remote Island Areas, and American Samoa* (PIFSC Data Report DR-17-001). Honolulu, HI: Pacific Island Fisheries Science Center.

Mearns, A. J., D. J. Reish, P. S. Oshida, T. Ginn, and M. A. Rempel-Hester. (2011). Effects of Pollution on Marine Organisms. *Water Environment Research, 83*(10), 1789–1852.

Merkel & Associates Inc. (2014). *2014 San Diego Bay Eelgrass Inventory Update* (Prepared for U.S. Navy Region Southwest Naval Facilities Engineering Command and San Diego Unified Port District). San Diego, CA: Merkel & Associates, Inc.

Mitsch, W. J., and J. G. Gosselink. (2007). *Wetlands* (Fourth ed.). Hoboken, NJ: John Wiley & Sons, Inc.

Mitsch, W. J., J. G. Gosselink, C. J. Anderson, and L. Zhang. (2009). *Wetland Ecosystems*. Hoboken, NJ: John Wiley & Sons, Inc.

Monterey Bay Aquarium Research Institute. (2009). *Marine Flora of Monterey*. Retrieved from http://www.mbari.org/staff/conn/botany/flora/mflora.htm.

Moore, K. A., H. A. Neckles, and O. R. J. (1996). *Zostera marina* (eelgrass) growth and survival along a gradient of nutrients and turbidity in the lower Chesapeake Bay. *Marine Ecology Progress Series, 124*, 247–259.

Moore, S., M. Sutula, T. Von Bitner, G. Lattin, and K. Schiff. (2016). *Southern California Bight 2013 Regional Monitoring Program: Volume III. Trash and Marine Debris*. (Technical Report 928). Costa Mesa, CA: Southern California Coastal Water Research Project.

Nagaoka, S., A. Martins, R. dos Santos, M. Tognella, E. de Oliveira Filho, and J. Seminoff. (2012). Diet of juvenile green turtles (*Chelonia mydas*) associating with artisanal fishing traps in a subtropical estuary in Brazil. *Marine Biology, 159*(3), 573–581.

National Centers for Coastal Ocean Science. (2010). *Economic Impacts of Harmful Algal Blooms*. Silver Spring, MD: Center for Sponsored Coastal Ocean Research. Retrieved from http://www.cop.noaa.gov/stressors/extremeevents/hab/current/econimpact_08.pdf.

National Marine Fisheries Service. (2002). *Final Recovery Plan for Johnson's Seagrass (Halophia johnsonni)*. Silver Spring, MD: National Marine Fisheries Service.

Neckles, H. A., F. T. Short, S. Barker, and B. S. Kopp. (2005). Disturbance of eelgrass, *Zostera marina,* by commercial mussel, *Mytilus edulis,* harvesting in Maine: Dragging impacts and habitat recovery. *Marine Ecology Progress Series, 285*, 57–73.

Nybakken, J. W. (1993). *Marine Biology, an Ecological Approach* (3rd ed.). New York, NY: Harper Collins College Publishers.

Olsen, Y. S., M. Sanchez-Camacho, N. Marba, and C. M. Duarte. (2012). Mediterranean seagrass growth and demography responses to experimental warming. *Estuaries and Coasts, 35*(5), 1205–1213.

Pandolfi, J. M., J. B. C. Jackson, N. Baron, R. H. Bradbury, H. M. Guzman, T. P. Hughes, C. V. Kappel, F. Micheli, J. C. Ogden, H. P. Possingham, and E. Sala. (2005). Are U.S. coral reefs on the slippery slope to slime? *Science, 307*(5716), 1725–1726.

Parrish, F. A., and R. C. Boland. (2004). Habitat and reef-fish assemblages of banks in the Northwestern Hawaiian Islands. *Marine Biology, 144*, 1065–1073.

Peterson, C. H. (2001). The "Exxon Valdez" oil spill in Alaska: Acute, indirect and chronic effects on the ecosystem. In A. J. Southward, P. A. Tyler, C. M. Young, & L. A. Fuiman (Eds.), *Advances in Marine Biology* (Vol. 39, pp. 1–103). San Diego, CA: Academic Press.

Phillips, R. C., and E. G. Meñez. (1988). Seagrasses. *Smithsonian Contributions to the Marine Sciences, 34*, 104.

Preskitt, L. (2001). *Halophila hawaiiana*. *Invasive Marine Algae of Hawai'i.* Retrieved from http://www.hawaii.edu/reefalgae/invasive_algae/seagrasses/halophia_hawaiiana.htm.

Preskitt, L. (2002a). *Halophila decipiens*. *Invasive Marine Algae of Hawai'i.* Retrieved from http://www.hawaii.edu/reefalgae/invasive_algae/seagrasses/halophila_decipiens.htm.

Preskitt, L. (2002b). *Edible Limu: Gifts from the Sea*. Retrieved from http://www.hawaii.edu/reefalgae/publications/ediblelimu/index.htm.

Preskitt, L. (2010). *Invasive Marine Algae of Hawaii*. Retrieved from http://www.hawaii.edu/reefalgae/invasive_algae/INDEX.HTM.

Ragazzola, F., L. C. Foster, C. J. Jones, T. B. Scott, J. Fietzke, M. R. Kilburn, and D. N. Schmidt. (2016). Impact of high CO_2 on the geochemistry of the coralline algae *Lithothamnion glaciale*. *Scientific Reports, 6*(20572), 1–9.

Ralph, P. J., and F. T. Short. (2002). Impact of the wasting disease pathogen, *Labyrinthula zosterae*, on the photobiology of eelgrass *Zostera marina*. *Marine Ecology Progress Series, 226*, 265–271.

Rodriguez, S., A. R. T. Santiago, and G. Shenker. (2001). *A Public-Access GIS-Based Model of Potential Species Habitat Distribution for the Santa Barbara Channel and the Channel Islands National Marine Sanctuary.* (Master's group project). University of California, Santa Barbara, Santa Barbara, CA.

Roskov, Y., L. Abucay, T. Orrell, D. Nicolson, T. Kunze, A. Culham, N. Bailly, P. Kirk, T. Bourgoin, R. E. DeWalt, W. Decock, and A. De Weaver. (2015). *Species 2000 & ITIS Catalogue of Life, 2015 Annual Checklist*. Retrieved from http://www.catalogueoflife.org/annual-checklist/2015/.

Ruggiero, M., and D. Gordon. (2015). *ITIS Standard Report Page: Ochrophyta*. Retrieved from http://www.itis.gov/servlet/SingleRpt/SingleRpt.

Ruwa, R. K. (1996). Intertidal wetlands. In T. R. McClanahan & T. P. Young (Eds.), *East African Ecosystems and Their Conservation* (pp. 101–130). New York, NY: Oxford University Press.

Sargent, F. J., T. J. Leary, D. W. Crewz, and C. R. Kruer. (1995). *Scarring of Florida's Seagrasses: Assessment and Management Options*. St. Petersburg, FL: Florida Department of Environmental Protection.

Schiel, D. R., J. R. Steinbeck, and M. S. Foster. (2004). Ten years of induced ocean warming causes comprehensive changes in marine benthic communities. *Ecology, 85*(7), 1833–1839.

Schnetzer, A., P. E. Miller, R. A. Schaffner, B. A. Stauffer, B. H. Jones, S. B. Weisberg, P. M. DiGiacomo, W. M. Berelson, and D. A. Caron. (2007). Blooms of *Pseudo-nitzschia* and domoic acid in the San Pedro Channel and Los Angeles harbor areas of the Southern California Bight, 2003–2004. *Harmful Algae, 6*, 372–387.

Setala, O., J. Norkko, and M. Lehtiniemi. (2016). Feeding type affects microplastic ingestion in a coastal invertebrate community. *Marine Pollution Bulletin, 102*, 95–101.

Smith, J. E., C. L. Hunter, and C. M. Smith. (2002). Distribution and reproductive characteristics of nonindigenous and invasive marine algae in the Hawaiian Islands. *Pacific Science, 56*(3), 299–315.

Spalding, M., M. Taylor, C. Ravilious, F. Short, and E. Green. (2003). Global overview: The distribution and status of seagrasses. In E. P. Green & F. T. Short (Eds.), *World Atlas of Seagrasses* (pp. 5–26). Berkeley, CA: University of California Press.

Spalding, M. D., C. Ravilious, and E. P. Green. (2001). *World Atlas of Coral Reefs*. Berkeley, CA: University of California Press.

Spalding, M. D., H. E. Fox, G. R. Allen, N. Davidson, Z. A. Ferdaña, M. Finlayson, B. S. Halpern, M. A. Jorge, A. Lombana, S. A. Lourie, K. D. Martin, E. McManus, J. Molnar, C. A. Recchia, and J. Roberston. (2007). Marine ecoregions of the world: A bioregionalisation of coastal and shelf areas. *Bioscience, 57*(7), 573–583.

Steneck, R. S., M. H. Graham, B. J. Bourque, D. Corbett, J. M. Erlandson, J. A. Estes, and M. J. Tegner. (2002). Kelp forest ecosystems: Biodiversity, stability, resilience and future. *Environmental Conservation, 29*(4), 436–459.

U.S. Department of the Navy. (2013). *San Diego Bay Integrated Natural Resources Management Plan*. San Diego, CA: Unified Port of San Diego.

U.S. Department of the Navy. (2014). *Marine Species Monitoring For the U.S. Navy's Hawaii Range Complex 2013 Annual Report*. Pearl Harbor, HI: U.S. Navy Pacific Fleet.

U.S. National Response Team. (2010). *What are the Effects of Oil on Seagrass?* Washington, DC: U.S. Environmental Protection Agency. Retrieved from http://www.nrt.org/production/NRT/RRTHome.nsf/resources/RRTIV-Pamphlets/$File/27_RRT4_Seagrass_Pamphlet.pdf.

Veron, J. (2000). *Corals of the World*. Cape Ferguson, Australia: Australian Institute of Marine Sciences and CRR Qld Pty Ltd.

Waggoner, B., and B. R. Speer. (1998). *Introduction to the Dinoflagellata*. Retrieved from http://www.ucmp.berkeley.edu/protista/dinoflagellata.html.

Wilson, C. (2002). *Giant Kelp (Macrocystis pyrifera)*. Retrieved from http://www.dfg.ca.gov/mlpa/response/kelp.pdf.

Wyllie-Echeverria, S., and J. D. Ackerman. (2003). The seagrasses of the Pacific coast of North America. In E. P. Green & F. T. Short (Eds.), *World Atlas of Seagrasses* (pp. 199–206). Berkeley, CA: University of California Press.

Young, M., K. Cavanaugh, T. Bell, P. Raimondi, C. A. Edwards, P. T. Drake, L. Erikson, and C. Storlazzi. (2016). Environmental controls on spatial patterns in the long-term persistence of giant kelp in central California. *Ecological Monographs, 86*(1), 45–60.

Zaitsev, Y. P. (1971). *Marine Neustonology*. Jerusalem, Israel: Israel Program for Scientific Translations.

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Final
Environmental Impact Statement/Overseas Environmental Impact Statement
Hawaii-Southern California Training and Testing

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3.4 INVERTEBRATES

PREFERRED ALTERNATIVE SYNOPSIS

The United States Department of the Navy considered all potential stressors that invertebrates could be exposed to from the Proposed Action. The following conclusions have been reached for the Preferred Alternative (Alternative 1):

- Acoustics: Invertebrates could be exposed to noise from the proposed training and testing activities. However, available information indicates that invertebrate sound detection is primarily limited to low frequency (less than 1 kilohertz [kHz]) particle motion and water movement that diminishes rapidly with distance from a sound source. The expected impact of noise on invertebrates is correspondingly diminished and mostly limited to offshore surface layers of the water column where only zooplankton, squid, and jellyfish are prevalent mostly at night when training and testing occur less frequently. Invertebrate populations are typically lower offshore, where most training and testing occurs, than inshore due to the scarcity of habitat structure and comparatively lower nutrient levels. Exceptions occur at nearshore and inshore locations where occasional pierside sonar, air gun, or pile driving actions occur near relatively resilient soft bottom or artificial substrate communities. Because the number of individuals affected would be small relative to population numbers, population-level impacts are unlikely.
- Explosives: Explosives produce pressure waves that can harm invertebrates in the vicinity of where they typically occur: mostly offshore surface waters where zooplankton, squid, and jellyfish are prevalent mostly at night when training and testing with explosives do not typically occur. Invertebrate populations are generally lower offshore than inshore due to the scarcity of habitat structure and comparatively lower nutrient levels. Exceptions occur where explosives are used on the bottom within nearshore or inshore waters on or near sensitive live hard bottom communities. Soft bottom communities are resilient to occasional disturbances. Due to the relatively small number of individuals affected, population-level impacts are unlikely.
- Energy: The proposed activities would produce electromagnetic energy that briefly affects a very limited area of water, based on the relatively weak magnetic fields and mobile nature of the stressors. Whereas some invertebrate species can detect magnetic fields, the effect has only been documented at much higher field strength than what the proposed activities would generate. High-energy lasers can damage invertebrates. However, the effects are limited to surface waters where relatively few invertebrate species occur (e.g., zooplankton, squid, jellyfish), mostly at night when actions do not typically occur, and only when the target is missed. Due to the relatively small number of individuals that may be affected, population-level impacts are unlikely.
- Physical Disturbance and Strike: Invertebrates could experience physical disturbance and strike impacts from vessels and in-water devices, military expended materials, seafloor devices, and pile driving. Most risk occurs offshore (where invertebrates are less abundant) and near the surface where relatively few invertebrates occur during the day when actions are typically occurring. The majority of expended materials are used in areas far from nearshore and inshore bottom areas where invertebrates are the most abundant. Exceptions occur for actions taking

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- Physical Disturbance and Strike (continued): place within inshore and nearshore waters over primarily soft bottom communities, such as related to vessel transits, inshore and nearshore vessel training, nearshore explosive ordnance disposal training, operation of bottom-crawling seafloor devices, and pile driving. Invertebrate communities in affected soft bottom areas are naturally resilient to occasional disturbances. Accordingly, population-level impacts are unlikely.
- Entanglement: Invertebrates could be entangled by various expended materials (wires, cables, decelerators/parachutes, biodegradable polymer). Most entanglement risk occurs in offshore areas where invertebrates are relatively less abundant. The risk of entangling invertebrates is minimized by the typically linear nature of the expended structures (e.g., wires, cables), although decelerators/parachutes have mesh that could pose a risk to those invertebrates that are large and slow enough to be entangled (e.g., jellyfish). Deep-water coral could also be entangled by drifting decelerators/parachutes, but co-occurrence is highly unlikely given the extremely sparse coverage of corals in the deep ocean. Accordingly, population-level impacts are unlikely.
- Ingestion: Small expended materials and material fragments pose an ingestion risk to some invertebrates. However, most military expended materials are too large to be ingested, and many invertebrate species are unlikely to consume an item that does not visually or chemically resemble its natural food. Exceptions occur for materials fragmented by explosive charges or weathering, which could be ingested by filter- or deposit-feeding invertebrates. Ingestion of such materials would likely occur infrequently, and only invertebrates located very close to the fragmented materials would potentially be affected. Furthermore, the vast majority of human-deposited ingestible materials in the ocean originate from non-military sources. Accordingly, population-level impacts are unlikely.
- Secondary: Secondary impacts on invertebrates are possible via changes to habitats (sediment or water) and to prey availability due to explosives, explosives byproducts, unexploded munitions, metals, and toxic expended material components. Other than bottom-placed explosives, the impacts are mostly in offshore waters where invertebrates are less abundant. The impacts of occasional bottom-placed explosives are mostly limited to nearshore soft bottom habitats that recover quickly from disturbance. Following detonation, concentrations of explosive byproducts are rapidly diluted to levels that are not considered toxic to marine invertebrates. Furthermore, most explosive byproducts are common seawater constituents. Contamination leaching from unexploded munitions is likely inconsequential because the material has low solubility in seawater and is slowly delivered to the water column. Heavy metals and chemicals such as unspent propellants can reach harmful levels around stationary range targets but are not likely in vast open waters where proposed action targets are typically mobile or temporarily stationary. Accordingly, overall impacts of secondary stressors on widespread invertebrate populations are not likely. Impacts due to decreased availability of prey items (fish and other invertebrates) would likely be undetectable.

3.4.1 INTRODUCTION

This chapter provides the analysis of potential impacts on marine invertebrates found in the Hawaii-Southern California Training and Testing (HSTT) Study Area (Study Area). This section provides an introduction to the species that occur in the Study Area.

The affected environment provides the context for evaluating the effects of the Navy training and testing activities on invertebrates. Because invertebrates occur in all habitats, activities that interact with the water column or the bottom could potentially impact many species and individuals, including microscopic zooplankton (e.g., invertebrate larvae, copepods, protozoans) that drift with currents, larger invertebrates living in the water column (e.g., jellyfish, shrimp, squid), and benthic invertebrates that live on or in the seafloor (e.g., clams, corals, crabs, worms). Because many benthic animals have limited mobility compared to pelagic species, activities that contact the bottom generally have a greater potential for impact. Activities that occur in the water column generally have a lesser potential for impact due to dilution and dispersion of some stressors (e.g., chemical contaminants), potential drifting of small invertebrates out of an impact area, and the relatively greater mobility of open water invertebrates large enough to actively leave an impact area.

The following subsections provide brief introductions to the major taxonomic groups and the Endangered Species Act (ESA)-listed species of marine invertebrates that occur in the Study Area. The National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) maintains a website that provides additional information on the biology, life history, species distribution (including maps), and conservation of invertebrates.

3.4.2 AFFECTED ENVIRONMENT

Three subsections are included in this section. General background information is given in Section 3.4.2.1 (General Background), which provides summaries of habitat use, movement and behavior, sound sensing and production, and threats that affect or have the potential to affect natural communities of marine invertebrates within the Study Area. Species listed under the ESA are described in Section 3.4.2.2 (Endangered Species Act-Listed Species). General types of marine invertebrates that are not listed under the ESA are reviewed in Section 3.4.2.3 (Species Not Listed Under the Endangered Species Act).

3.4.2.1 General Background

Invertebrates, which are animals without backbones, are the most abundant life form on Earth, with marine invertebrates representing a large, diverse group with approximately 367,000 species described worldwide to date (World Register of Marine Species Editorial Board, 2015). However, it is estimated that most existing species have not yet been described (Mora et al., 2011). The total number of invertebrate species that occur in the Study Area is unknown, but is likely to be many thousands. The results of a research effort to estimate the number of marine invertebrate species in various areas identified nearly 6,000 species in the Insular Pacific Hawaii large marine ecosystem and over 8,000 species in the California Current large marine ecosystem (Fautin et al., 2010). Invertebrate species vary in their use of abiotic habitats and some populations are threatened by human activities and other natural changes, especially endangered species.

Marine invertebrates are important ecologically and economically, providing an important source of food, essential ecosystem services (coastal protection, nutrient recycling, food for other animals, habitat formation), and income from tourism and commercial fisheries (Spalding et al., 2001). The health and abundance of marine invertebrates are vital to the marine ecosystem and the sustainability of the world's fisheries (Pauly et al., 2002). Economically important invertebrate groups that are fished, commercially and recreationally, for food in the United States include crustaceans (e.g., shrimps, lobsters, and crabs), bivalves (e.g., scallops, clams, and oysters), echinoderms (e.g., sea urchins and sea cucumbers), and cephalopods (e.g., squids and octopuses) (Chuenpagdee et al., 2003; Food and Agriculture Organization of the United Nations, 2005; Pauly et al., 2002). Marine invertebrates or the structures they form (e.g., shells and coral colonies) are harvested for many purposes including jewelry, curios, and the aquarium trade. In addition, some marine invertebrates are sources of chemical compounds with potential medical applications. Natural products have been isolated from a variety of marine invertebrates and have shown a wide range of therapeutic properties, including anti-microbial, antioxidant, anti-hypertensive, anticoagulant, anticancer, anti-inflammatory, wound healing and immune modulation, and other medicinal effects (De Zoysa, 2012).

3.4.2.1.1 Habitat Use

Marine invertebrates live in all of the world's oceans, from warm shallow waters to cold deep waters. They inhabit the bottom and all depths of the water column in both large marine ecosystems (Insular Pacific-Hawaiian and California Current) and the open-ocean area (North Pacific Subtropical Gyre) that occur in the Study Area (Brusca & Brusca, 2003). Many species that occur in the water column are either microscopic or not easily observed with the unaided eye (e.g., protozoans, copepods, and the larvae of larger invertebrate species). Many invertebrates migrate to deeper waters during the day, presumably to decrease predation risk. However, some invertebrates, such as some jellyfish and squid species, may occur in various portions of the water column, including near the surface, at any time of day. In addition, under certain oceanographic conditions, other types of invertebrates (e.g., pelagic crabs and by-the-wind sailors [*Velella velella*]) may occur near the surface during the day. The Study Area extends from the bottom up to the mean high tide line (often termed mean high water in literature). The description of habitat use in this section pertains to common marine invertebrates found in the different habitats. This section also identifies marine invertebrates that form persistent habitats, which are considered to be structures that do not quickly disintegrate or become incorporated into soft or intermediate substrate after the death of the organism. The principal habitat-forming invertebrates are corals and shellfish species (e.g., oysters, mussels). In a strict sense, individual invertebrates with hard shells (e.g., molluscs), outer skeletons (e.g., crabs), tubes (e.g., annelid worms), or cavities (e.g., sponges) also may be habitat-forming, providing attachment surfaces or living spaces for other organisms. The abiotic (nonliving) components of all habitat types are addressed in Section 3.5 (Habitats), and marine vegetation components are discussed in Section 3.3 (Vegetation).

Marine invertebrate distribution in the Study Area is influenced by habitat (e.g., abiotic substrate, topography, biogenic [formed by living organisms] features), ocean currents, and physical and water chemistry factors such as temperature, salinity, and nutrient content (Levinton, 2009). Distribution is also influenced by distance from the equator (latitude) and distance from shore. In general, the number of marine invertebrate species (species richness) increases toward the equator (Cheung et al., 2005; Macpherson, 2002). Species richness and overall abundance are typically greater in coastal water habitats compared to the open ocean due to the increased availability of food and protection that coastal habitats provide (Levinton, 2009).

The diversity and abundance of Arthropoda (e.g., crabs, lobsters, and barnacles) and Mollusca (e.g., snails, clams, and squid) are highest on the bottom over the continental shelf due to high productivity and availability of complex habitats relative to typical soft bottom habitat of the deep ocean (Karleskint et al., 2006). Organisms occurring in the bathyal and abyssal zones of the ocean are generally small and have sparse populations (Nybakken, 1993). The deep ocean has a limited food supply for sedentary deposit or filter feeders. The only areas of the deep ocean known to be densely populated are hydrothermal vents and cold seeps (refer to Section 3.5, Habitats, for additional information on these features).

Sandy coastal shores are dominated by species that are adapted to living in shifting substrates, many of which are highly mobile and can burrow. In Hawaii, mole crabs (species name was not provided in the report, but was presumably the Pacific mole crab, *Hippa pacifica*), polychaete worms, and auger snails (*Terebra* species) were identified as common species in the swash zone of sandy beaches (Hawaii Department of Land and Natural Resources, 1980). Studies of coastal locations on Molokai (primarily rocky intertidal areas but also including some sand patches) identified various crabs, amphipods, isopods, worms, and molluscs as observed or expected species (Godwin & Bolick, 2006; Minton & Carnevale, 2006). Common invertebrates of southern California beaches include common sand crab (*Emerita analoga*) and a variety of isopods, amphipods, bivalves, snails, worms, and insects (Dugan et al., 2000; Dugan et al., 2015). Inland soft shores consist of mud flats and sand flats that occur in areas sheltered from strong currents and waves. Soft shore habitats may support a wide variety of invertebrate species including crabs, shrimp, clams, snails, and numerous species of worms. Polychaete worms and crabs are common invertebrates on tidal mud flats in Hawaii (U.S. Fish and Wildlife Service, 2011). Invertebrates documented in tidal flats in southern California include numerous taxa of worms, crustaceans, and molluscs (Talley et al., 2000; Thompson et al., 1993). California horn snail (*Cerithidea californica*) is the dominant invertebrate of mud flats.

Intermediate (e.g., cobble, gravel) and rocky shores provide habitat for a variety of marine invertebrates (e.g., sea anemones, barnacles, chitons, limpets, mussels, urchins, sea stars, sponges, tunicates, and various worms). Rocky intertidal invertebrates may be attached or free living/mobile, and use various feeding strategies (filter-feeders, herbivores, carnivores, scavengers). Many invertebrates occurring in rocky intertidal zones are preyed upon by fish, birds, and other invertebrates. The black abalone (*Haliotis cracherodii*) and white abalone (*Haliotis sorenseni*), which are listed as endangered species under the ESA, occur infrequently in southern California rocky intertidal and subtidal habitats (see Section 3.4.2.2.1, Black Abalone [*Haliotis cracherodii*], and Section 3.4.2.2.2, White Abalone [*Haliotis sorenseni*]). Hard artificial structures such as pier pilings and seawalls can have a community of invertebrates that is similar to that of rocky habitats.

Vegetated habitats, such as eelgrass in embayments and protected soft bottom coastal areas, surfgrass on rocky intertidal and nearshore subtidal habitat, and kelp forests in nearshore subtidal habitats, support a wide variety of marine invertebrate species. Eelgrass provides important habitat for invertebrates in southern California (Bernstein et al., 2011). More than 50 species of invertebrates occur in surfgrass beds of San Diego County (Stewart & Myers, 1980). Surfgrass also serves as the primary nursery habitat for the commercially important California spiny lobster (*Panuliris interruptus*). Several hundred species of invertebrates have been reported in giant kelp forests of California, in association with rocky substratum, kelp holdfasts, and as epiphytes on kelp blades (Foster & Schiel, 1985).Conspicuous or commonly observed invertebrates in kelp forests include cnidarians (sea anemones, gorgonian sea fans), sponges, arthropod crustaceans (crabs, California spiny lobster), molluscs (abalone, keyhole limpet, octopus, nudibranchs, sea hares), echinoderms (sea cucumbers, sea stars, sea urchins), and tunicates.

Rocky reefs and other rocky habitats may occur in subtidal zones. Invertebrate species composition associated with rocky subtidal habitats may be influenced by depth, size, and structural complexity of the habitat. Hundreds of invertebrate species may occur in rocky habitats, which provide attachment sites for sessile (attached to the bottom) species such as barnacles, bryozoans, limpets, sea anemones, sea fans, sponges, and tunicates, among others. Other invertebrates move about or shelter in crevices, including crustaceans (e.g., crabs, lobsters), echinoderms (e.g., brittle stars, sea cucumbers, sea urchins, sea stars), and molluscs (e.g., snails, nudibranchs, sea hares, octopus).

Shallow-water coral reefs are formed by individual corals with symbiotic, structure-forming algae that require both light and a mean annual water temperature greater than about 64 degrees Fahrenheit (National Ocean Service, 2016b; Nybakken, 1993). Shallow-water corals occur in the euphotic zone, which is the upper layer of the ocean where light levels are sufficient to support photosynthesis in the symbiotic algae. Shallow-water coral species typically occur in water depths less than 30 meters (m). Shallow-water coral reefs occur on hard substrate throughout the Hawaii Range Complex. In addition to the presence of many individual corals, coral reefs also support hundreds of other marine invertebrate species, including representatives of most taxa. The amount of hard reef structure covered by living corals, species richness, and species diversity in the Main Hawaiian Islands remained steady over the time period of 1999 to 2012, with total coverage estimated at about 24 percent, although there was notable variation at individual islands (Rodgers et al., 2015). Coral coverage is below 20 percent at most surveyed locations in the Northwestern Hawaiian Islands, and the coverage appears to have remained stable over the time period of 1981 to 2005, based on survey results at established monitoring sites (Friedlander et al., 2008a). Coral bleaching and mortality events were documented in portions of the Hawaiian archipelago in 2014 and 2015 (Bahr et al., 2015; Bahr et al., 2017), reducing the amount of live coral coverage in some areas. Surveyed areas that were affected by coral bleaching generally appeared to recover by the end of 2016, but researchers caution that potential future increases in severity and frequency of bleaching events could result in decreased coral coverage in the region (Bahr et al., 2015; Bahr et al., 2017). Seven species of shallow-water corals dominate waters of the Main Hawaiian Islands: lobe coral (*Porites lobata*), finger coral (*P. compressa*), rice coral (*Montipora capitata*), sandpaper rice coral (*M. patula*), blue rice coral (*M. flabellata*), cauliflower coral (*Pocillopora meandrina*), and corrugated coral (*Pavona varians*) (Friedlander et al., 2008b). Lobe coral is the dominant species at numerous locations in the Northwestern Hawaiian Islands, while table coral (*Acropora cytherea*), cauliflower coral, and rice coral are abundant at some locations (Friedlander et al., 2008a).

Deep-water corals occur in water depths where there is low or no light penetration and therefore typically lack symbiotic algae. As such, deep-water corals do not typically form biogenic reefs, but rather form mounds of intermediate (cobble-sized) substrate termed “lithoherms” over hard bottom areas (Lumsden et al., 2007). Differences in water clarity and the resulting light penetration at various locations affect the specific depth at which deep-water corals are found. However, in general, deep-water species are considered to occur at depths below 50 m (National Ocean and Atmospheric Administration, 2016; National Oceanic and Atmospheric Administration & National Marine Fisheries Service, 2008). To build their supporting structures, stony corals require calcium carbonate in the form of aragonite or calcite, which they obtain from seawater where carbonate is in solution. Combinations of temperature and pressure result in a boundary, often called the saturation depth, below which aragonite and calcite tend to dissolve. Therefore, corals (and other invertebrates) occurring below this boundary have difficulty forming persistent structures that contain calcium carbonate, and the aragonite saturation boundary imposes a depth limit for stony coral occurrence. The depth of the saturation boundary varies in different locations, ranging from about 200 to 3,000 m. Accordingly, deep-water corals are found in the depth range of about 50 to 3,000 m (Bryan & Metaxas, 2007; Lumsden et al., 2007; Quattrini et al., 2015; Tittensor et al., 2009). The primary taxa of deep-water corals include hexacorals (stony corals, black corals, and gold corals), octocorals (e.g., true soft corals, gorgonians, and sea pens), and hydrocorals (e.g., lace corals) (Hourigan et al., 2017a). Of the approximately 600 coral species that occur at depths below 50 m, about 20 are considered structure forming (Hourigan et al., 2017a). Stony corals such as *Enallopsammia rostrata* provide three-dimensional structure that may be utilized by other marine species. However, taxa such as black corals, gorgonians, and sea pens may also provide habitat for other marine species, particularly when they occur in dense aggregations. With the exception of sea pens, which occur in soft substrate, deep-water corals generally attach to hard or intermediate substrates exposed to strong currents that provide a steady supply of plankton (algae and small animals that drift in the water) to feed on, and that reduce sedimentation that would inhibit colonization and growth of these slow-growing species (Bryan & Metaxas, 2007; Tsao & Morgan, 2005). Spatial information on the hard and intermediate substrate habitats typically occupied by deep-water structure-forming corals is provided in Section 3.5 (Habitats).

A transition zone of reduced light levels, called the mesophotic zone, occurs between the water depths typically associated with shallow-water and deep-water corals. Mesophotic coral communities are composed of stony corals, soft corals, and other structure-forming organisms such as algae and sponges. Some corals with symbiotic, photosynthetic algae occur in the mesophotic zone, although the algae often undergo photosynthesis at reduced rates and the corals, therefore, rely more heavily on planktonic food capture compared to individuals that occur in the euphotic zone. Black corals and octocorals, which do not contain photosynthetic algae, are also characteristic of mesophotic communities. The depth range of the mesophotic zone depends on water clarity, but it is generally considered to extend from 30 m to about 100 to 150 m. Mesophotic communities may occur as deeper extensions of shallow-water reefs or other hard bottom communities (typically in the coastal zone), or they may occur in offshore locations with no connection to shallow-water communities. Mesophotic reefs are usually not detectable on satellite images, which increases the difficulty of identifying and mapping these features. The highest concentrations of stony corals typically occur on persistent, high-relief bottom features that represent a small subset of the hard and, to a lesser extent, intermediate substrates of the Study Area. Spatial information on the hard and intermediate habitats typically occupied by mesophotic structure-forming corals is provided in Section 3.5 (Habitats). In the Study Area, mesophotic coral communities occur throughout the Hawaiian Archipelago (Baker et al., 2016). Due to water clarity, corals containing photosynthetic algae occur at depths up to about 150 m in some portions of the Hawaii region.

Chemosynthetic communities may support a relatively high biomass of marine invertebrates. Instead of using photosynthesis driven by sunlight, chemosynthetic organisms derive energy from chemicals originating from the earth's crust. The primary types of habitats supporting chemosynthetic communities are hydrothermal vents and cold seeps. Hydrothermal vents form when seawater permeates downward through the earth's crust and upper mantle, becomes superheated, and removes minerals and chemicals from the crust. The heated fluid may then rise through fissures in the crust and reach cold ocean water at the seafloor, where metals and other minerals precipitate out to form mounds or chimneys. Communities of microbes, such as bacteria, may colonize these structures and use chemicals occurring in the fluid (primarily hydrogen sulfide or methane) to make energy. The microbes may then become the base of a food web that contains invertebrates such as crabs, clams, mussels, worms, snails, and shrimp (Ross et al., 2012; Woods Hole Oceanographic Institution, 2015). Cold seeps are similar to hydrothermal vents, but the fluid exiting the crust is cooler, typically moves at a slower rate, and may spread over a larger area. Methane hydrates (ice-like structures that contain methane) are associated with some chemosynthetic communities. Cold seeps are generally associated with hard substrate on offshore shelf breaks, submarine canyons, and seamounts; refer to Section 3.5 (Habitats) for spatial information on the habitats typically occupied by chemosynthetic communities.

In the Hawaiian Islands, a hydrothermal vent field was documented on the summit of Lo'ihi Seamount (located near the main island of Hawaii) in the 1950s (Garcia et al., 2005). In 1996, seismic events formed a large crater on the summit and destroyed the vent area; however, new vents later re-formed (Wheat et al., 2000). Cold seeps have been found in association with multiple fault systems off southern California, including the San Clemente (Bernardino & Smith, 2010; Torres et al., 2002), San Pedro (Paull et al., 2008), and San Diego Trough faults (Grupe et al., 2015).

3.4.2.1.2 Movement and Behavior

Marine benthic and epibenthic (animals that live on the surface of the substrate) invertebrates may be sessile, sedentary (limited mobility), or highly mobile (but typically slower than large vertebrates). Several beach invertebrates (e.g., sand crabs, Pismo clams [*Tivela stultorum*], polychaete worms) recruit to beaches during spring and summer and seasonally move to shallow nearshore waters during late fall and winter. Some subtidal epibenthic invertebrates undergo seasonal onshore-offshore migrations associated with reproduction (e.g., California spiny lobster).

Pelagic marine invertebrates include plankton (organisms that do not swim or generally cannot swim faster than water currents) and nekton (active swimmers that can generally swim faster than water currents). Planktonic animals commonly undergo daily migrations to surface waters at dusk and return to deeper waters at dawn. This includes small, microscopic zooplankton and larvae, larger crustaceans (e.g., small shrimp), and jellyfish. Planktonic organisms vary in their swimming abilities, ranging from weak (e.g., larvae) to substantial (e.g., box jellyfish). Nekton such as prawns, shrimps, and squid have relatively strong swimming ability, although they are typically slower than most vertebrate animals.

3.4.2.1.3 Sound Sensing and Production

In general, organisms may detect sound by sensing either the particle motion or pressure component of sound, or both (refer to Appendix D, Acoustic and Explosive Concepts, for an explanation of these sound components). Aquatic invertebrates probably do not detect pressure since many are generally the same density as water and few, if any, have air cavities that would respond to pressure (Budelmann, 1992b; Popper et al., 2001). Marine invertebrates are generally thought to perceive sound via either external sensory hairs or internal statocysts. Many aquatic invertebrates have ciliated "hair" cells that may be sensitive to water movements, such as those caused by currents or water particle motion very close to a sound source (Budelmann, 1992a, 1992b; Mackie & Singla, 2003). This may allow sensing of nearby prey or predators, or help with local navigation. Detection of particle motion is thought to occur in mechanical receptors found on various body parts (Roberts et al., 2016a). Aquatic invertebrates that are able to sense local water movements with ciliated cells include cnidarians, flatworms, segmented worms, molluscs, and arthropods (Budelmann, 1992a, 1992b; Popper et al., 2001). Crustaceans in particular seem to have extensive occurrence of these structures. The sensory capabilities of adult corals are largely limited to detecting water movement using receptors on their tentacles (Gochfeld, 2004), and the exterior cilia of coral larvae likely help them detect nearby water movements (Vermeij et al., 2010).

Some aquatic invertebrates have specialized organs called statocysts that enable an animal to determine orientation, balance, and, in some cases, linear or angular acceleration. Statocysts allow the animal to sense movement and may enable some species, such as cephalopods and crustaceans, to be sensitive to water particle movements associated with sound or vibration (Hu et al., 2009; Kaifu et al., 2008;

Montgomery et al., 2006; Normandeau Associates, 2012; Popper et al., 2001). Because any acoustic sensory capabilities, if present, are apparently limited to detecting the local particle motion component of sound (Edmonds et al., 2016), and because water particle motion near a sound source falls off rapidly with distance, aquatic invertebrates are probably limited to detecting nearby sound sources rather than sound caused by pressure waves from distant sources.

In addition to hair cells and statocysts that allow some marine invertebrates to detect water particle motion, some species also have sensory organs called chordotonal organs that can detect substrate vibrations. Chordotonal organs are typically attached to connective tissue of flexible appendages such as antennae and legs (Edmonds et al., 2016). The structures are connected to the central nervous system and can detect some movements or vibrations that are transmitted through substrate.

Available information indicates that aquatic invertebrates are primarily sensitive to low-frequency sounds. Both behavioral and auditory brainstem response studies suggest that crustaceans may sense sounds up to 3 kHz, but greatest sensitivity is likely below 200 hertz (Hz) (Goodall et al., 1990; Lovell et al., 2005; Lovell et al., 2006). Most cephalopods (e.g., octopus and squid) likely sense low-frequency sound below 1 kHz, with best sensitivities at lower frequencies (Budelmann, 1992b; Mooney et al., 2010; Packard et al., 1990). A few cephalopods may sense frequencies up to 1.5 kHz (Hu et al., 2009). Squid did not respond to playbacks of odontocete (e.g., toothed whales) ultrasonic echolocation clicks, likely because these clicks were outside of squid hearing range (Wilson et al., 2007). Although information on the frequency range of the clicks was not provided, ultrasonic sound typically refers to high frequency sounds above the limit of human hearing (greater than about 20 kHz). Similarly, squid did not respond to killer whale echolocation clicks ranging from 199 to 226 decibels (dB) referenced to 1 micropascal (dB re 1 µPa) (Wilson et al., 2007) (refer to Appendix D, Acoustic and Explosive Concepts, for an explanation of this and other acoustic terms). The frequency of the clicks was not provided. However, killer whale echolocation clicks have been reported to be mostly between 45 and 80 kHz (Au et al., 2004). Some researchers have suggested sensitivity to sounds of higher frequencies in some species, although study results are inconclusive. European spiny lobsters (*Palinurus elephas*), some of which were exposed to predators, were found to produce ultrasound signals up to about 75 kHz (Buscaino et al., 2011). The investigators speculated that the signals might have an anti-predator function or might be used in intraspecific communication, although these functions (particularly communication) were considered hypothetical. The results of another study suggest that European spiny lobsters likely use acoustic signals to aggregate (frequency was not specified, although lobsters in the study produced sounds of up to 30 kHz) (Filiciotto et al., 2014). However, information currently available indicates that invertebrates are likely sensitive only to local water movement and to low-frequency particle accelerations generated in their close vicinity (Normandeau Associates, 2012).

Although many types of aquatic invertebrates produce sound and at least some species have the ability to detect low-frequency particle motion, little is known about the use of sound or whether all sound production is purposeful or merely incidental in some cases (Hawkins et al., 2015; Normandeau Associates, 2012). Some invertebrates have structures that appear to be designed specifically for sound production, and the results of various studies (summarized in the following paragraphs) indicate that sound is used for communication or other behaviors in some species. For example, it has been suggested by numerous researchers that the larvae of some marine species (e.g., crustaceans, molluscs, and corals) use sound cues for directional orientation (Budelmann, 1992a, 1992b; Montgomery et al., 2006; Popper et al., 2001).

Aquatic invertebrates may produce and use sound in territorial behavior, to detect or deter predators, and in reproduction (Popper et al., 2001). Some crustaceans produce sound by rubbing or closing hard body parts together (Au & Banks, 1998; Heberholz & Schmitz, 2001; Latha et al., 2005; Patek & Caldwell, 2006). The snapping shrimp chorus makes up a significant portion of the ambient noise in many locations (Au & Banks, 1998; Cato & Bell, 1992; Heberholz & Schmitz, 2001). Each snapping shrimp click is up to 215 dB re 1 µPa at 1 m (root mean square [rms] is implied, but the authors did not explicitly state sound pressure level [SPL] or peak SPL), with a peak around 2 to 5 kHz. Some crustaceans, such as the American lobster (*Homarus americanus*) and California mantis shrimp (*Hemisquilla californiensis*), may also produce sound by vibrating the carapace (Henninger & Watson, 2005; Patek & Caldwell, 2006). Spiny lobsters typically produce low-frequency rasps by moving a structure at the base of the antennae over a rigid file (Buscaino et al., 2011). Other crustaceans make low-frequency rasping or rumbling noises, perhaps used in defense or territorial display (Patek & Caldwell, 2006; Patek et al., 2009), or perhaps used incidental to a visual display. The aquatic isopod *Cymodoce japonica* produces sound by rubbing body parts together (Nakamachi et al., 2015).

Reef noises, such as fish pops and grunts, sea urchin grazing (around 1 kHz), parrotfish grazing, and snapping shrimp noises (around 5 kHz) (Radford et al., 2010), may be used as a cue by some aquatic invertebrates. Nearby reef noises were observed to affect movements and settlement behavior of coral and crab larvae (Jeffs et al., 2003; Radford et al., 2007; Stanley et al., 2010; Vermeij et al., 2010), although chemical cues and substrate color are also used by some species (Foster & Gilmour, 2016). Larvae of other crustacean species, including pelagic and nocturnally emergent species that benefit from avoiding coral reef predators, appear to avoid reef noises (Simpson et al., 2011). Detection of reef noises is likely limited to short distances. Low-frequency sound pressure and particle motion have been measured near a coral reef off Maui, Hawaii (Kaplan & Mooney, 2016). Results indicate that adult cephalopod species would not be able to detect the low level of particle acceleration at the measurement point nearest the reef (50 m). The specific particle acceleration levels detected by marine invertebrate larvae are unknown, but the authors suggest that invertebrate larvae would be unlikely to detect particle acceleration at distances beyond 150 m at this reef. Playback of reef sounds increased the settlement rate of eastern oyster (*Crassostrea virginica*) larvae (Lillis et al., 2013). Green-lipped mussel (*Perna canaliculus*) larvae settlement rate increased when exposed to underwater noise produced by a ferry (Wilkens et al., 2012).

3.4.2.1.4 General Threats

General threats to marine invertebrates include overexploitation and destructive fishing practices (Halpern et al., 2008; Jackson et al., 2001; Kaiser et al., 2002; Miloslavich et al., 2011; Pandolfi et al., 2003), habitat degradation resulting from pollution and coastal development (Cortes & Risk, 1985; Downs et al., 2009; Mearns et al., 2011), disease (Porter et al., 2001), invasive species (Bryant et al., 1998; Galloway et al., 2009; Wilkinson, 2002) (which may be introduced as a result of growth on vessel hulls or bilge water discharge), oil spills (Yender et al., 2010), global climate change and ocean acidification (Hughes et al., 2003), and possibly human-generated noise (Brainard et al., 2011; Vermeij et al., 2010). A relatively new threat to marine invertebrates is bioprospecting, which is the collection of organisms in pursuit of new compounds for development of pharmaceutical products (Radjasa et al., 2011). Numerous bioactive products have been isolated from marine invertebrates collected in the Hawaii Exclusive Economic Zone (Leal et al., 2012).

Compared to many other invertebrate taxa, the threats to corals are well-studied. Numerous natural and human-caused stressors may affect corals of the Main Hawaiian Islands, including thermal stress, disease, tropical storms, coastal development and pollution, erosion and sedimentation, tourism/recreation, fishing, trade in coral and live reef species, vessel anchoring or groundings, marine debris, predation, invasive species, military and other security-related activities, and hydrocarbon exploration (Center for Biological Diversity, 2009; National Oceanic and Atmospheric Administration, 2008a, 2008b). Stressors associated with the Northwestern Hawaiian Islands are similar but, in the case of direct human-caused impacts, lesser in degree because the islands are more remote. Coral bleaching, which occurs when corals expel the symbiotic algae living in their tissues, is a stress response to changes in environmental parameters such as temperature or light. Compared to other regions of the world, few major coral bleaching events have occurred in the Hawaiian Islands. The first known large-scale bleaching event occurred in 1996, primarily affecting portions of the Main Hawaiian Islands. A second event occurred in 2002 in the Northwestern Hawaiian Islands (Jokiel & Borwn, 2004). More recently, bleaching events were documented at Kane'ohe Bay on the northeast coast of Oahu in 2014 (Bahr et al., 2015) and other portions of the Main Hawaiian Islands in 2014 and 2015 (National Oceanic and Atmospheric Administration, 2015). In Kane'ohe Bay, susceptibility to bleaching, severity of impacts, and recovery time was strongly influenced by the type of symbiotic algae, varying coping mechanisms in individual corals, and abiotic (e.g., hydrodynamics) factors (Cunning et al., 2016). Factors that seem to be important for coral reef resilience (ability of a reef to resist and recover from environmental disturbance) were identified by McClanahan et al. (2012). Some factors are large in scale and difficult to manage, while others, such as fishing methods and adjacent watershed pollution, are more easily affected by local management practices. The National Oceanic and Atmospheric Administration's Pacific Islands Fisheries Science Center evaluated numerous areas of the Main Hawaiian Islands in relation to these factors and developed composite resiliency scores. Generally, the highest scores were associated with sparsely populated areas (e.g., Ni'ihau, portions of Maui), while the lowest scores were associated with densely populated areas (e.g., portions of O'ahu) (Pacific Islands Fisheries Science Center, 2014). Primary threats to deep-water or cold-water corals include bottom fishing, hydrocarbon exploration, cable and pipeline placement, and waste disposal (e.g., discarded or lost rope and fishing equipment, dredged sediments) (Freiwald et al., 2004).

Threats related to water quality, marine debris, and climate change are further described in the subsections below.

3.4.2.1.4.1 Water Quality

Invertebrates may be affected by changes in water quality resulting from pollution, turbidity and increased particle deposition that may occur as a result of sediment disturbance, and waste discharge. Stormwater runoff and point source discharges associated with coastal development may introduce pollutants into bays and other nearshore coastal areas. The pollutants may degrade sediment and water quality, which in turn can impact marine invertebrate communities. Sediment disturbance may result from activities such as dredging, which can affect sensitive species such as some corals (Erftemeijer et al., 2012). In addition to dredging, erosion due to storm runoff may cause changes in the frequency or magnitude of sedimentation in areas in proximity to ocean outfalls, estuarine inlets, and major river discharges.

Ship discharges may affect water quality and invertebrates associated with the impacted water. Discharged materials include sewage, bilge water, graywater, ballast water, and solid waste (e.g., food and garbage). Discharges may originate from military, commercial, and recreational vessels. Under provisions of the Clean Water Act, the U.S. Environmental Protection Agency (USEPA) and the U.S. Department of Defense have developed Uniform National Discharge Standards to address discharges from U.S. military vessels. Refer to Section 3.2.1.2.2 (Federal Standards and Guidelines) for more information on water quality, including Uniform National Discharge Standards.

Marine invertebrates can be impacted by exposure to oil due to runoff from land, natural seepage, or accidental spills from offshore drilling/extraction or tankers (White et al., 2012). Reproductive and early life stages are especially sensitive to oil exposure. Factors such as oil type, quantity, exposure time, and season can affect the toxicity level. Experiments using corals indicate that oil exposure can result in death, decreased reproductive success, altered development and growth, and altered behavior (White et al., 2012; Yender et al., 2010).

3.4.2.1.4.2 Climate Change

The primary concerns of climate change in the context of impacts on marine invertebrates include increased water temperature, ocean acidification, increased frequency or intensity of cyclonic storm events, and sea level rise.

Increases in ocean temperature can lead to coral stress, bleaching, and mortality (Lunden et al., 2014). Bleaching of corals and other invertebrates that contain symbiotic algae in their tissues (e.g., some anemones and clams) is often tied to atypically high sea temperatures (Lough & van Oppen, 2009; National Ocean Service, 2016a). Bleaching events have increased in frequency in recent decades. Coral bleaching on a global scale occurred during the summers of 2014, 2015, and 2016 (Eakin et al., 2016). In addition to elevated sea temperatures, atypically low sea temperatures may also cause mortality to corals and most other reef organisms (Colella et al., 2012; Lirman et al., 2011; National Ocean Service, 2016a), suggesting that widening climate extremes could cause more coral bleaching. In one experiment, three coral species that experienced bleaching had reduced ability to remove sediments from their tissue surface (Bessell-Browne et al., 2017). Response to thermal stress may differ across species or within different environmental contexts, with some species or taxa being more tolerant than others (Bahr et al., 2016; Guest et al., 2016; Hoadley et al., 2015). For example, in the Caribbean Sea, while numerous stony corals may be negatively affected by increased water temperature, some gorgonian corals have been found to persist or increase in abundance under similar conditions (Goulet et al., 2017). The results of one study suggest that some corals may acclimate to increased water temperature over time, exhibiting less temperature sensitivity and resulting bleaching activity (McClanahan, 2017). Skeletal formation of post-settlement individuals of the plate coral *Acropora spicifera* was not affected by increased water temperature (Foster et al., 2016). However, exposure to lowered pH was found to increase the potential for negative effects associated with subsequent water temperature increase in one stony coral species (Towle et al., 2016). In addition to potential physiological effects, the distribution of some invertebrates may be affected by changing water temperature. Northern and southern shifts in the geographic center of abundance of some benthic invertebrates along the U.S. Atlantic coast have occurred over the last 20 years, presumably in response to increased water temperature (Hale et al., 2017).

Ocean acidification has the potential to reduce calcification and growth rates in species with calcium carbonate skeletons, including shellfish (e.g., clams, oysters), corals, and sponges (Clark & Gobler, 2016; Cohen et al., 2009), and crustose coralline algae that contain calcite in their cell walls (Roleda et al., 2015). For example, newly settled individuals of the plate coral *A. spicifera* that were exposed to elevated carbon dioxide and lowered pH levels showed decreased mineral deposition and evidence of skeletal malformation (Foster et al., 2016), and water acidification decreased the survival, size, and weight of bay barnacles (*Balanus improvises*) (Pansch et al., 2018). The results of one study suggest that community-level effects to corals can be more evident than effects to individual corals (Carpenter et al., 2018). Many species within these taxa are important structure-building organisms. In addition to corals and shellfish, acidification may also affect weakly calcified taxa such as lobsters and sea cucumbers (Small et al., 2016; Verkaik et al., 2016). Some climate change models predict that the depth below which corals are unable to form calcium carbonate skeletons will become shallower as the oceans acidify and temperatures increase, potentially decreasing the occurrence and habitat-forming function of corals and other invertebrates. Deep-sea scleractinian stony corals could be particularly vulnerable due to habitat loss and decreased larvae dispersal (Miller et al., 2011). However, a recent study of successive generations of shallow-water reef-building corals exposed to increased water temperature and acidification suggests some corals may be able to tolerate rapidly changing environmental conditions better than previously thought (Putnam & Gates, 2015). In addition to physical effects, increased acidity may result in behavioral changes in some species. For example, acidification of porewater was found to affect burrowing behavior and juvenile dispersal patterns of the soft-shell clam (*Mya arenaria*) (Clements et al., 2016), and increased acidity caused a reduction in the loudness and number of snaps in the snapping shrimp *Alpheus novaezelandiae* (Rossi et al., 2016). As discussed for thermal stress, some invertebrate species may be more tolerant of changing acidity levels than others (Bahr et al., 2016). One study found that lowered pH caused a significant decrease in black band disease progression in mountainous star coral (Muller et al., 2017). Another study of three Arctic marine bivalves concluded that at least two of the species are generally resilient to decreased pH (Goethel et al., 2017). A study of the deep-water stony coral *Desmophyllum dianthus* found that the species was not affected by increased acidity under conditions of ambient water temperature but that stress and decreased calcification occurred when acidity and water temperature were both increased (Murray et al., 2016). Gelatinous invertebrates such as jellyfish generally seem to be tolerant of increased water acidity (Treible et al., 2018).

Although the potential effects that climate change could have on future storm activity is uncertain, numerous researchers suggest that rising temperatures could result in little change to the overall number of storms, but that storm intensity could increase (Voiland, 2013). Increased storm intensity could result in increased physical damage to individual corals and reefs constructed by the corals (which support numerous other invertebrate taxa), overturning of coral colonies, and a decrease in structural complexity due to disproportionate breakage of branching species (Heron et al., 2008; The Nature Conservancy, 2015). However, large storms such as hurricanes may also have positive impacts on corals, such as lowering the water temperature and removing less resilient macroalgae from reef structures, which can overgrow corals.

Sea level rise could affect invertebrates by modifying or eliminating habitat, particularly estuarine and intertidal habitats bordering steep and artificially hardened shorelines (Fujii, 2012). It is possible that intertidal invertebrates would colonize newly submerged areas over time if suitable habitat is present. Coral reef growth may be able to keep pace with sea level rise because accretion rates of individual corals are generally greater than projected potential rates of sea level rise (The Nature Conservancy, 2016). Corals are currently subjected to tidal fluctuations of up to several meters (The Nature Conservancy, 2015; U.S. Geological Survey, 2016). However, the overall net accretion rate of coral reefs may be much slower than the rate of individual corals, decreasing the overall ability of reefs to keep pace with rising water levels. In addition, the compounding effect of other stressors (e.g., ocean acidification) is unknown. In an evaluation of threats to corals previously petitioned for listing under the ESA, sea level rise was considered a low to medium influence on extinction risk (Brainard et al., 2011).

Additional concerns include the potential for changes in ocean circulation patterns that affect the planktonic food supply of filter- and suspension-feeding invertebrates (e.g., corals) (Etnoyer, 2010). An increase in the future incidence of diseases in marine organisms is also theorized (Harvell et al., 2002). In addition, there is concern that cumulative effects of threats from fishing, pollution, and other human disturbance may reduce the tolerance of corals to global climate change (Ateweberhan & McClanahan, 2010; Ateweberhan et al., 2013).

3.4.2.1.4.3 Marine Debris

Marine debris (especially plastics) is a threat to many marine ecosystems, particularly in coastal waters adjacent to urban development. Microplastics (generally considered to be particles less than 5 millimeters in size), which may consist of degraded fragments of larger plastic items or intentionally manufactured items (e.g., abrasive plastic beads found in some personal care products or used in blast-cleaning), are of concern because of their durability and potential to enter marine food webs (Setala et al., 2016). Field and laboratory investigations have documented ingestion of microplastics by marine invertebrates including bivalve molluscs; crustacean arthropods such as lobsters, shore crabs, and amphipods; annelid lugworms; and zooplankton (Browne et al., 2013; Setala et al., 2014; Von Moos et al., 2012; Watts et al., 2014). While animals with different feeding modes have been found to ingest microplastics, laboratory studies suggest that filter-feeding and deposit feeding benthic invertebrates are at highest risk (Setala et al., 2016). Refer to Section 3.2 (Sediments and Water Quality) for a more detailed discussion of marine debris and the associated effects on water quality.

Marine debris, including large amounts of plastic, is present in surface waters around the Main Hawaiian Islands and Northwestern Hawaiian Islands, and is found on coral reefs as well (Cooper & Corcoran, 2010; Dameron et al., 2007). The Hawaiian Archipelago is located within the North Pacific Gyre, which consolidates debris originating in various areas of the Pacific Ocean. However, there have been no surveys specifically conducted to investigate marine debris on the seafloor in Hawaii. A visual survey of the seafloor that included a portion of the Navy's Southern California Range Complex was conducted as part of a 15-year quantitative assessment of marine debris on the seafloor off the California coast (Watters et al., 2010). Plastics were the most abundant material found and, along with recreational monofilament fishing line, dominated the debris encountered on the seafloor. U.S. Navy vessels have a zero-plastic discharge policy and return all plastic waste to appropriate disposal or recycling sites on shore. The visual survey encountered only a single object that was potentially "military" in origin (it appeared to be a shell casing). A survey conducted at Monterey Canyon off California found that items of military origin were among the least frequently encountered types of identified debris (Schlining et al., 2013).

Recent studies in the Southern California Bight found that marine debris (primarily plastic) occurred in about one-third of seafloor areas surveyed (Moore et al., 2016). Microplastic particles were more prevalent in shallow nearshore areas (ports, marinas, bays, and estuaries) than in offshore areas. Another study of marine debris along the U.S. West Coast characterized the composition and abundance of man-made marine debris at 1,347 randomly selected stations during groundfish bottom trawl surveys that took place in 2007 and 2008 (Keller et al., 2010). The sample sites included some locations within the southern California portion of the HSTT Study Area. A subset of the sites sampled included historically used post-WWII dump sites. Recovered items identifying the sites as post-WWII era dump sites included equipment described as "helmets," "gas masks," "uniforms," and other miscellaneous and diverse items such as "plastic," "file cabinets," and "buckets." Since approximately the 1970s, items such as these are no longer disposed of at sea. The items listed here are not military expended materials and would not be expended during training and testing activities in the HSTT Study Area. For this reason, the characterization of "military debris" in the study has little if any relevance to the Proposed Action or to present-day standard Navy conduct that includes (among other procedures) restrictions on the discharge of plastics at sea.

3.4.2.2 Endangered Species Act-Listed Species

As shown in Table 3.4-1, there are four species of invertebrates listed as Endangered or Species of Concern under the ESA in the Study Area. Two abalone species listed as endangered are discussed in Section 3.4.2.2.1 (Black Abalone [*Haliotis cracherodii*]) and Section 3.4.2.2.2 (White Abalone [*Haliotis sorenseni*]). Two other abalone species, green abalone (*Haliotis fulgens*) and pink abalone (*Haliotis corrugata*), are species of concern. Species of concern are those for which NMFS has some concern regarding status and threats, but for which insufficient information is available to indicate a need to list them under the ESA. The species of concern designation does not impose any procedural or substantive requirements under the ESA.

NMFS has identified the overall primary factors contributing to decline of the abalone species shown in Table 3.4-1 (National Oceanic and Atmospheric Administration Fisheries, 2015). These factors are overharvesting, low population density, loss of genetic diversity, disease, poaching, and natural predation. Navy training and testing activities are not expected to contribute substantially to any of these factors.

Table 3.4-1: Status of Endangered Species Act-Listed Species Within the Study Area

Species Name and Regulatory Status			*Presence in Study Area*		
Common Name	**Scientific Name**	**Endangered Species Act Status**	**Open Ocean Area/Transit Corridor**	**California Current Large Marine Ecosystem**	**Insular Pacific-Hawaiian Large Marine Ecosystem**
Black abalone	*Haliotis cracherodii*	Endangered	None	Yes	None
White abalone	*Haliotis sorenseni*	Endangered	None	Yes	None
Green abalone	*Haliotis fulgens*	Species of Concern	None	Yes	None
Pink abalone	*Haliotis corrugata*	Species of Concern	None	Yes	None

3.4.2.2.1 Black Abalone (*Haliotis cracherodii*)

3.4.2.2.1.1 Status and Management

The black abalone (*Haliotis cracherodii*) was listed as endangered under the ESA in 2009. A dramatic decline in abundance, likely caused by a disease known as withering syndrome (explained in more detail below), prompted closure of both the commercial and recreational fisheries in California. The State of California imposed a moratorium on black abalone harvesting throughout California in 1993 and on all abalone harvesting in central and southern California in 1997 (Butler et al., 2009). Numerous California State Marine Protected Areas provide additional protection for abalone. An Abalone Recovery Management Plan was adopted by the State of California in 2005.

NMFS prepared a status review for this species in 2009 (Butler et al., 2009), and announced in 2016 the intent to prepare an updated status review (Endangered and Threatened Species; Initiation of 5-Year Review for the Endangered Black Abalone and the Endangered White Abalone, 81 *Federal Register* 93902–93903 [December 22, 2016]). Critical habitat was designated for black abalone by NMFS in 2011

(Endangered and Threatened Wildlife and Plants: Final Rulemaking to Designate Critical Habitat for Black Abalone, 76 *Federal Register* 66806–66844 [October 27, 2011]). Designated critical habitat includes rocky intertidal and subtidal habitats from the mean higher high water line to a depth of approximately 6 m), as well as the waters encompassed by these areas. Designated critical habitat generally extends from Del Mar Landing Ecological Reserve to the Palos Verdes Peninsula, and includes several offshore islands, including waters surrounding Santa Catalina and Santa Barbara Islands. No training or testing activities occur in waters surrounding these islands (the training activities occur in open ocean portions). The specific areas proposed for designation off San Nicolas and San Clemente Islands were determined to be ineligible for designation because the Navy's Integrated Natural Resources Management Plans provide benefits to black abalone in those areas. The critical habitat designation also identifies physical or biological features of the habitat, which are the features that support the life-history needs of the species. The physical or biological features considered essential for black abalone recovery are rocky substrate, food resources, juvenile settlement habitat, suitable water quality, and suitable nearshore circulation patterns.

Various projects are in place to monitor the status of the species, to understand and address withering disease, to improve reproduction, and to minimize illegal harvest. For instance, the Navy monitors black abalone populations on San Clemente and San Nicolas Islands and Point Loma, San Diego, and the species is managed under both the San Clemente Island Integrated Natural Resources Management Plan and San Nicolas Island Integrated Natural Resources Management Plan. The Navy has conducted and provided funding for surveys of rocky intertidal areas on San Clemente Island, San Nicolas Island, and Point Loma, including surveys specifically for black abalone (Graham et al., 2014; Tierra Data, 2008).

3.4.2.2.1.2 Habitat and Geographic Range

The distribution of black abalone ranges approximately from Point Arena in northern California to Bahia Tortugas and Isla Guadalupe in Mexico (Butler et al., 2009). Although the geographic range of black abalone extends to northern California, the most abundant populations historically have occurred in the Channel Islands (Butler et al., 2009). A map of the black abalone range can be accessed on NMFS Office of Protected Resources website.

Black abalone live on rocky substrates in the high to low intertidal zone (with most animals found in the middle and lower intertidal) within the southern California portion of the HSTT Study Area. They occur among other invertebrate species, including California mussels (*Mytilus californianus*), gooseneck barnacles (*Pollicipes polymerus*), and sea anemones (e.g., giant green anemone (*Anthopleura xanthogrammica*). Of the species of abalone in the waters of California, the black abalone inhabits the shallowest areas. It is rarely found deeper than 6 m, and smaller individuals generally inhabit the higher intertidal zones. Complex surfaces with cracks and crevices may be crucial habitat for juveniles, and appear to be important for adult survival as well (Butler et al., 2009).

3.4.2.2.1.3 Population Trends

Black abalone were generally abundant before 1985 in the coastal waters throughout the species' range, although abundance has historically not been considered high north of San Francisco. Substantial populations also occurred in the coastal waters of the Channel Islands of southern California. In the early 1970s, the black abalone constituted the largest abalone fishery in California. Black abalone populations south of Monterey County, California, have experienced 95 percent or greater declines in abundance since the mid-1980s as a result of fishing pressure in combination with withering syndrome (Neuman et al., 2010). Withering syndrome is caused by the bacteria species *Candidatus Xenohaliotis californiensis*, which attacks the lining of the abalone's digestive tract, inhibiting the production of digestive enzymes, which ultimately causes the muscular "foot" to wither and atrophy. This impairs the abalone's ability to adhere to rocks (Butler et al., 2009), making it more vulnerable to predation or starvation.

Major declines in abundance in the Channel Islands, the primary fishing grounds for this species before closure of the abalone fishery, have severely reduced the population as a whole (Butler et al., 2009). Recent surveys of rocky intertidal habitat at San Clemente Island have resulted in a total population estimate of approximately 100 to 300 individuals of black abalone, representing less than 0.1 percent of historical levels on the island (Raimondi et al., 2012; Tierra Data, 2008). Surveys of rocky shores in 2013 indicate black abalone continue to be rare at San Clemente Island (Graham et al., 2014).

The Black Abalone Status Review Team estimates that, unless effective measures are put in place to counter the population decline caused by withering syndrome and overfishing, the species will likely be extinct within 30 years (Butler et al., 2009). San Nicolas Island is one of the only locations in southern California where black abalone have been increasing and where multiple recruitment events have occurred since 2005 (Butler et al., 2009).

3.4.2.2.1.4 Predator and Prey Interactions

The black abalone diet varies with life history stage. As larvae, black abalone receive nourishment from their egg yolks and do not actively feed. Settled abalone clamp tightly to rocky substrates and feed on crustose coralline algal matter that they scrape from the rocks. Young juveniles feed on bottom-dwelling diatoms, bacterial films, and microflora. As they increase in size and become less vulnerable to predation, abalone move into more open locations on rocks (though still cryptic) to forage. Adult black abalone feed primarily on drifting plant fragments and attached macroalgae (Butler et al., 2009; Smith et al., 2003). The primary predators of abalone are fish, sea otters, sea stars, and a variety of invertebrates, as well as humans through illegal harvesting (National Oceanic and Atmospheric Administration Fisheries, 2018; Smith et al., 2003).

3.4.2.2.1.5 Species-Specific Threats

The black abalone population is declining as a consequence of historical overfishing and ongoing threats of withering syndrome, illegal harvest, pollution, and natural predation. The spread of withering syndrome is enhanced by periods of ocean warming, such as El Niño events (Neuman et al., 2010). Although there is no documented causal link between withering syndrome and long-term climate change, historical patterns suggest that ocean warming may increase the susceptibility of black abalone to the disease. Decreased population density is an additional factor in the species decline (Neuman et al., 2010). The black abalone is a broadcast spawner (gametes released into the water and fertilization occurs externally), and simultaneous spawning by males and females in close proximity (within a few feet [ft.]) is required for successful reproduction. In areas where black abalone have been overfished or otherwise reduced, the distance between adult males and females may be too great or the population density too low to sustain local populations (Butler et al., 2009; Neuman et al., 2010). There is some concern that the invasive macroalga *Sargassum horneri*, first documented off southern California in 2003 and currently distributed in coastal waters from Santa Barbara to central Baja California, Mexico, has the potential to affect black abalone populations. Long-term ecological implications of the presence of the invasive species are uncertain but potentially include displacement of native kelp (Kaplanis et al., 2016; Marks et al., 2015), which is a food source for black abalone.

3.4.2.2.2 White Abalone (*Haliotis sorenseni*)

3.4.2.2.2.1 Status and Management

The white abalone (*Haliotis sorenseni*) was listed as endangered under the ESA in 2001 and is recognized as one stock (Hobday & Tegner, 2000). Overfishing in the 1970s reduced the population to such low densities that successful reproduction was severely restricted. White abalone populations continue to be threatened primarily by reproductive failure (Hobday et al., 2001; National Marine Fisheries Service & Southwest Regional Office, 2008). Critical habitat is not designated for this species.

The State of California suspended all forms of harvesting of the white abalone in 1996 and, in 1997, imposed an indefinite moratorium on the harvesting of all abalone in central and southern California (National Marine Fisheries Service & Southwest Regional Office, 2008). NMFS determined that informing the public of the locations of critical habitat, which includes areas where white abalone still exist, would increase the risk of illegal harvesting of white abalone (National Marine Fisheries Service & Southwest Regional Office, 2008). Potential habitat may exist between Point Conception, California, and the California/Mexico border, with much of it occurring in the isolated, deep waters off the Channel Islands. In reaction to concerns over the status of white abalone, the White Abalone Restoration Consortium was formed to propagate a captive-reared stock to enhance the depleted wild stock (National Marine Fisheries Service & Southwest Regional Office, 2008). There is now a captive breeding program at the Bodega Bay Marine Laboratory, University of California Davis, in partnership with several facilities throughout California.

3.4.2.2.2.2 Habitat and Geographic Range

The white abalone is a well-concealed, sessile, bottom-dwelling species that prefers reefs and rock piles with low relief areas surrounded by sandy areas (Hobday & Tegner, 2000). White abalone in the Southern California Bight typically inhabit depths ranging from about 20 to 60 m, with the highest densities occurring between 40 and 50 m (Butler et al., 2006). White abalone were found in waters deeper than other west coast abalone species (Hobday et al., 2001). Overall, habitat associations of white abalone depend on its main food sources, drift macroalgae and a variety of red algae (National Oceanic and Atmospheric Administration, 2018). Thus, depth distribution is limited by water clarity and light penetration as well as by the availability of hard substrate or anchoring points on the bottom (Butler et al., 2006). Evidence suggests that white abalone prefer the sand and rock interface at the reef's edge, rather than the middle sections of reefs. Sand channels may be important for movement and concentration of drifting fragments of macroalgae and red algae (National Marine Fisheries Service & Southwest Regional Office, 2008). Postlarval and juvenile individuals often occur in sheltered areas to decrease susceptibility to predation, while adults occur in more open areas.

White abalone were historically found between Point Conception, California, and Punta Abreojos, Baja California, Mexico, at depths as shallow as 5 m (National Marine Fisheries Service & Southwest Regional Office, 2008). The northern portion of the range includes the San Clemente (Navy-owned) and Santa Catalina Islands in the northeastern corner of the southern California portion of the HSTT Study Area (Butler et al., 2006; National Marine Fisheries Service & Southwest Regional Office, 2008). On the southern end of the range, the species was common around a number of islands, including Isla Cedros and Isla Natividad, Mexico (Hobday & Tegner, 2000). The current range in California appears similar to that of the historical range, although the species occurs in extremely reduced numbers. Information on the current range off Baja California is not available (National Marine Fisheries Service & Southwest Regional Office, 2008).

Except for some isolated survivors, the species is distributed only around the Channel Islands and along various banks within the Study Area (Hobday & Tegner, 2000; Rogers-Bennett et al., 2002). The species is known to occur off San Clemente, Santa Catalina, and Santa Barbara Islands and at Tanner and Cortes Banks (approximately 50 miles southwest of San Clemente Island). Both these banks are underwater mountains that occur off the coast of southern California. One study documented 5 square miles of available white abalone habitat at Tanner Bank, 4 square miles at Cortes Bank, and 3 square miles on the western side of San Clemente Island (Butler et al., 2006).

3.4.2.2.2.3 Population Trends

White abalone were once abundant throughout their range, but were more common and abundant along the coast in the northern and southern portions. Since the 1970s, the white abalone population has experienced a 99 percent reduction in density (National Marine Fisheries Service & Southwest Regional Office, 2008). Between 2002 and 2010, decreases in abundance (approximately 78 percent) and density (33 to 100 percent depending on depth and survey year) have been reported at Tanner Bank, an area of historically high abundance (greater than one animal per square meter [m^2]) (Butler et al., 2006). An increase in the size distribution over this same time period suggests individuals in the white abalone population are growing larger (which indicates increased age) with little or no indication of adequate recruitment success. With a dispersed population of aging individuals, prospects for recruitment remain low without management intervention, such as outplanting of healthy, captive-bred white abalone in suitable habitat (Stierhoff et al., 2012). Captive breeding programs are currently in place to develop white abalone for introduction into the ocean, but outplanting has not occurred to date (National Oceanic and Atmospheric Administration, 2018; University of California Davis, 2017). Personnel at the Space and Naval Warfare Systems Center at San Diego have previously outplanted green abalone (Navy Currents Magazine, 2011), but have not done so with additional abalone species.

Various researchers have conducted submersible surveys off Tanner and Cortes Banks to map abalone habitat structure, examine distribution, and estimate the population size (Butler et al., 2006; Davis et al., 1998; Hobday & Tegner, 2000). They recorded 258 animals, with 168 recorded on Tanner Bank in 2002, at depths ranging from 32 to 55 m. In 2004, 35 individuals were recorded at Tanner Bank, 12 at Cortes Bank, and 5 off San Clemente Island. The 2012 population estimate of 564 individuals at San Clemente Island represented a moderate increase from the estimate of 353 individuals in 2005 (Stierhoff et al., 2014).

In July 2016, the U.S. Navy and NMFS entered into a 7-year Memorandum of Agreement to fund projects benefitting white abalone recovery (U.S. Department of the Navy & National Oceanic and Atmospheric Administration, 2016). The activities, which include field and laboratory projects, will be focused on Tanner and Cortes Banks, but will also occur at San Clemente Island and Point Loma. Programs included in the agreement consist of field surveys and management assessments, development of tagging methods, disease studies, genetic evaluation, and outplanting monitoring.

3.4.2.2.2.4 Predator and Prey Interactions

Similar to black abalone, the white abalone diet varies with life history stage. As larvae, white abalone do not actively feed while in the planktonic stage. After settling on suitable substrate, abalone clamp tightly to rocky substrates and feed on algal matter scraped from the rocks or trapped under their shells. Young juveniles feed on bottom-dwelling diatoms, bacterial films, and benthic microflora. As they increase in size and become less vulnerable to predation, abalone leave their sheltered habitat to forage. Adult white abalone feed primarily on drifting fragments and attached macroalgae (National Marine Fisheries Service & Southwest Regional Office, 2008). Predators of white abalone include sea otters, fish, sea stars, crabs, spiny lobsters, and octopuses, as well as humans through illegal harvesting (Hobday & Tegner, 2000).

3.4.2.2.2.5 Species-Specific Threats

White abalone face similar threats to those of the black abalone (i.e., historical overharvesting, current low population densities, withering syndrome, competition with urchins and other abalone species for food, and illegal harvest). Low population density and illegal harvest are considered the primary current threats (National Marine Fisheries Service & Southwest Regional Office, 2008). However, because of the small population of white abalone, impacts on the remaining population are magnified.

3.4.2.3 Species Not Listed Under the Endangered Species Act

Thousands of invertebrate species occur in the Study Area; however, the only species with ESA status are the black abalone and white abalone (endangered), and the green abalone and pink abalone (species of concern). The variety of species spans many taxonomic groups (taxonomy is a method of classifying and naming organisms). Many species of marine invertebrates are commercially or recreationally fished. Several species are federally managed as part of fisheries under the Magnuson-Stevens Fishery Conservation and Management Act.

Marine invertebrates are classified within major taxonomic groups, generally referred to as a phylum. Major invertebrate phyla—those with greater than 1,000 species (Roskov et al., 2015; World Register of Marine Species Editorial Board, 2015)—and the general zones they inhabit in the Study Area are listed in Table 3.4-2. Vertical distribution information is generally shown for adults; the larval stages of most of the species occur in the water column. In addition to the discrete phyla listed, there is a substantial variety of single-celled organisms, commonly referred to as protozoan invertebrates, that represent several phyla (Kingdom Protozoa in Table 3.4-2). Throughout the invertebrates section, organisms may be referred to by their phylum name or, more generally, as marine invertebrates.

Table 3.4-2: Major Taxonomic Groups of Marine Invertebrates in the Hawaii-Southern California Training and Testing Study Area

Major Invertebrate Groups[1]		*Presence in Study Area*[2]	
Common Name (Classification)[3]	**Description**[4]	**Open Ocean**	**Coastal Waters**
Foraminifera, radiolarians, ciliates (Kingdom Protozoa)	Benthic and planktonic single-celled organisms; shells typically made of calcium carbonate or silica.	Water column, bottom	Water column, bottom
Sponges (Porifera)	Mostly benthic animals; sessile filter feeders; large species have calcium carbonate or silica structures embedded in cells to provide structural support.	Bottom	Bottom
Corals, anemones, hydroids, jellyfish (Cnidaria)	Benthic and pelagic animals with stinging cells; sessile corals are main builders of coral reef frameworks.	Water column, bottom	Water column, bottom
Flatworms (Platyhelminthes)	Mostly benthic; simplest form of marine worm with a flattened body.	Water column, bottom	Water column, bottom
Ribbon worms (Nemertea)	Benthic marine worms with an extendable, long tubular-shaped extension (proboscis) that helps capture food.	Water column bottom	Bottom

Table 3.4-2: Major Taxonomic Groups of Marine Invertebrates in the Hawaii-Southern California Training and Testing Study Area (continued)

Major Invertebrate Groups[1]		*Presence in Study Area*[2]	
Common Name (Classification)[3]	**Description**[4]	**Open Ocean**	**Coastal Waters**
Round worms (Nematoda)	Small benthic marine worms; free-living or may live in close association with other animals.	Water column, bottom	Water column, bottom
Segmented worms (Annelida)	Mostly benthic, sedentary to highly mobile segmented marine worms (polychaetes); free-living and tube-dwelling species; predators, scavengers, herbivores, detritus feeders, deposit feeders, and filter or suspension feeders.	Bottom	Bottom
Bryozoans (Bryozoa)	Small, colonial animals with gelatinous or hard exteriors with a diverse array of growth forms; filter feeding; attached to a variety of substrates (e.g., rocks, plants, shells or external skeletons of invertebrates).	Bottom	Bottom
Cephalopods, bivalves, sea snails, chitons (Mollusca)	Soft-bodied benthic or pelagic predators, filter feeders, detritus feeders, and herbivore grazers; many species have a shell and muscular foot; in some groups, a ribbon-like band of teeth is used to scrape food off rocks or other hard surfaces.	Water column, bottom	Water column, bottom
Shrimp, crabs, lobsters, barnacles, copepods (Arthropoda)	Benthic and pelagic predators, herbivores, scavengers, detritus feeders, and filter feeders; segmented bodies and external skeletons with jointed appendages.	Water column, bottom	Water column, bottom
Sea stars, sea urchins, sea cucumbers (Echinodermata)	Benthic animals with endoskeleton made of hard calcareous structures (plates, rods, spicules); five-sided radial symmetry; many species with tube feet; predators, herbivores, detritus feeders, and suspension feeders.	Bottom	Bottom

[1] Major species groups (those with more than 1,000 species) are based on the World Register of Marine Species (World Register of Marine Species Editorial Board, 2015) and Catalogue of Life (Roskov et al., 2015).
[2] Presence in the Study Area includes open ocean areas (North Pacific Gyre and North Pacific Transition Zone) and coastal waters of two large marine ecosystems (California Current and Insular-Pacific Hawaiian). Occurrence on or within seafloor (bottom or benthic) or water column (pelagic) pertains to juvenile and adult stages; however, many phyla may include pelagic planktonic larval stages.
[3] Classification generally refers to the rank of phylum, although Protozoa is a traditionally recognized group of several phyla of single-celled organisms (e.g., historically referred to as Kingdom Protozoa, which is still retained in some references, such as in the Integrated Taxonomic Information System).
[4] benthic = a bottom-dwelling organism associated with seafloor or substrate; planktonic = an organism (or life stage of an organism) that drifts in pelagic (water) environments; nekton = actively swimming pelagic organism

Additional information on the biology, life history, and conservation of marine invertebrates can be found on the websites maintained by the following organizations:

- NMFS, particularly for ESA-listed species and species of concern
- United States Coral Reef Task Force
- MarineBio Conservation Society
- Waikiki Aquarium
- Monterey Bay Aquarium

3.4.2.3.1 Foraminiferans, Radiolarians, Ciliates (Kingdom Protozoa)

Foraminifera, radiolarians, and ciliates are miniscule singled-celled organisms, sometimes forming colonies of cells, belonging to the kingdom Protozoa (Appeltans et al., 2010; Castro & Huber, 2000b). They are found in the water column and on the bottom of the world's oceans, and while most are microscopic, some species grow to approximately 20 centimeters (cm) (Hayward et al., 2016). In general, the distribution of foraminifera, radiolarians, and ciliates is patchy, occurring in regions with favorable growth conditions.

Foraminifera such as the genus *Globergerina* occur in the waters of the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems. Foraminifera form diverse and intricate shells out of calcium carbonate, organic compounds, or sand or other particles cemented together (University of California Berkeley, 2010a). The shells of foraminifera that live in the water column eventually sink to the bottom, forming soft bottom sediments known as foraminiferan ooze. Foraminifera feed on diatoms and other small organisms. Their predators include copepods and other zooplankton.

Radiolarians are microscopic zooplankton that form shells made of silica. Radiolarian ooze covers large areas of soft bottom habitat on the ocean floor (Pearse et al., 1987; University of California Berkeley, 2010e). Many radiolarian species contain symbiotic dinoflagellates (a type of single-celled organism) or algae. Radiolarians may also trap small particles or other organisms (e.g., diatoms) that drift in the water column.

Ciliates are protozoans with small hair-like extensions that are used for feeding and movement. They are a critical food source for primary consumers and are considered important parasites of many marine invertebrates. Ciliates feed on bacteria and algae, and some species contain symbiotic algae.

3.4.2.3.2 Sponges (Phylum Porifera)

Sponges include approximately 8,550 marine species worldwide and are classified in the Phylum Porifera (Van Soest et al., 2012; World Register of Marine Species Editorial Board, 2015). Sponges are bottom-dwelling, multicellular animals that can be best described as an aggregation of cells that perform different functions. Sponges are largely sessile, and are common throughout the Study Area at all depths. Sponges are typically found on intermediate bottoms (unconsolidated substrate that is mostly gravel or cobble-sized) to hard bottoms, artificial structures, and biotic reefs. Sponges reproduce both sexually and asexually. Water flow through the sponge provides food and oxygen, and removes wastes (Pearse et al., 1987; University of California Berkeley, 2010c). This filtering process is an important coupler of processes that occur in the water column and on the bottom (Perea-Blázquez et al., 2012). Many sponges form calcium carbonate or silica spicules or bodies embedded in cells to provide structural support (Castro & Huber, 2000b; Van Soest et al., 2012). Sponges provide homes for a variety of animals including shrimp, crabs, barnacles, worms, brittle stars, sea cucumbers, and other sponges (Colin & Arneson, 1995b). Common native species in the Insular Pacific-Hawaiian Large Marine

Ecosystem include lobate sponge (*Suberites zeteki*) and *Spongia oceania* (De Laubenfels, 1950, 1951), although some introduced species have become widespread as well. Sponges in the genera *Farrea*, *Hyalonema*, and *Suberites* occur in the waters of the California Current Large Marine Ecosystem (Clarke et al., 2015). Some sponge species are harvested commercially.

3.4.2.3.3 Corals, Hydroids, Jellyfish (Phylum Cnidaria)

There are over 10,000 marine species within the phylum Cnidaria worldwide (World Register of Marine Species Editorial Board, 2015), although there is taxonomic uncertainty within some groups (Veron, 2013). Cnidarians are organized into four classes: Anthozoa (corals, sea anemones, sea pens, sea pansies), Hydrozoa (hydroids and hydromedusae), Scyphozoa (true jellyfish), and Cubozoa (box jellyfish, sea wasps). Individuals are characterized by a simple digestive cavity with an exterior mouth surrounded by tentacles. Microscopic stinging capsules known as nematocysts are present (especially in the tentacles) in all cnidarians and are a defining characteristic of the phylum. The majority of species are carnivores that eat zooplankton, small invertebrates, and fishes. However, many species feed on plankton and dissolved organic matter, or contain symbiotic dinoflagellate algae (zooxanthellae) that produce nutrients by photosynthesis (Brusca & Brusca, 2003; Dubinsky & Berman-Frank, 2001; Lough & van Oppen, 2009; National Oceanic and Atmospheric Administration & NOAA's Coral Reef Conservation Program, 2016). Representative predators of cnidarians include sea slugs, snails, crabs, sea stars, coral- and jellyfish-eating fish, and marine turtles. Cnidarians may be solitary or may form colonies.

Cnidarians have many diverse body shapes, but may generally be categorized as one of two basic forms: polyp and medusa. The polyp form is tubular and sessile, attached at one end with the mouth surrounded by tentacles at the free end. Corals and sea anemones are examples of the polyp form. The medusa form is bell- or umbrella-shaped (e.g., jellyfish), with tentacles typically around the rim. The medusa form generally is pelagic, although there are exceptions. Many species alternate between these two forms during their life cycle. All cnidarian species are capable of sexual reproduction, and many cnidarians also reproduce asexually. The free-swimming larval stage is usually planktonic, but is benthic in some species.

A wide variety of cnidarian species occur throughout the Study Area at all depths and in most habitats, including hard and intermediate shores; soft, intermediate, and hard bottom; aquatic vegetation beds; and artificial substrates. Some cnidarians form biotic habitats that harbor other animals and influence ecological processes, the primary examples being shallow-water and deep-water stony corals. In this section, corals are discussed in terms of individual coral polyps or early life stages, where "coral" is defined as follows: Species of the phylum Cnidaria, including all species of the orders Antipatharia (black corals), Scleractinia (stony corals), Gorgonacea (horny corals), Stolonifera (organ pipe corals and others), Alcyonacea (soft corals), and Helioporacea (blue coral) of the class Anthozoa; and all species of the families Milleporidea (fire corals) and Stylastreridae (*stylasterid hydrocorals*) of the class Hydrozoa. Precious corals are non-reef building and inhabit depth zones below the euphotic zone. They are found on solid substrate in areas that are swept relatively clean by moderate-to-strong (greater than 25 cm/second) bottom currents. Precious corals may be divided into deep- and shallow-water species. Deep-water precious corals are generally found between 350 and 1,500 m and include pink coral (*Corallium secundum*), gold coral (*Gerardia* spp. and *Parazoanthus* spp.), and bamboo coral (*Lepidisis olapa*). Shallow water species occur between 30 and 100 m and consist primarily of three species of black coral: *Antipathes dichotoma*, *Antipathes grandis*, and *Antipathes ulex*.

Corals occur throughout the Hawaiian Archipelago. Approximately 250 species of corals are found in the region, including 59 scleractinian stony corals, 137 species of octocorals, 14 genera of black coral, 12 species of soft coral, and 4 species of stylasterid hydrocorals (Maragos et al., 2004). Dominant coral species in the Main Hawaiian Islands include *M. capitata*, *M. flabellata*, *M. patula*, *P. meandrina*, *P. compressa*, *P. lobata*, and *P. varians* (Franklin et al., 2013; Friedlander et al., 2008b). Common scleractinian corals of mesophotic reefs include several species of the genus *Leptoseris* (Kahng & Maragos, 2006). Coral coverage is generally highest in the southern portion of the archipelago (Friedlander et al., 2008b). However, more species of stony corals have been documented in the Northwestern Hawaiian Islands (57) than in the Main Hawaiian Islands (50) (Friedlander et al., 2008a; Friedlander et al., 2008b; Jokiel, 2008).

Although corals in temperate waters are not reef-building, the corals provide vertical relief and habitat that supports many organisms. For example, a single dead colony of Christmas tree black coral (*Antipathes dendrochristos*) observed by submersible off southern California was colonized by over 2,500 individual invertebrates, including other cnidarians (sea anemones and corals), crustaceans, echinoderms, molluscs, and polychaete worms (Love et al., 2007). Surveys using trawls, submersibles, and remotely operated vehicles conducted on outer continental shelf bank and rock outcrops off southern California have documented numerous coral species, including scleractinian stony corals, antipatharian black corals, gorgonian octocorals (sea fans), alcyonacean soft corals, pennatulacean octocorals (sea pens), and stylasterine hydrocoral (Etnoyer & Morgan, 2003; Whitmire & Clarke, 2007; Yoklavich et al., 2013).

Corals that are associated with tropical shallow reefs and temperate rocky habitats are vulnerable to a range of threats, including fishing impacts, pollution, erosion/sedimentation, coral harvesting, vessel damage, temperature increase, and climate change. Fishing practices such as blast fishing and trapping may be particularly destructive to coral reefs. In addition, removal of herbivorous fishes may result in overgrowth of coral reefs by algae (DeMartini & Smith, 2015). Because corals are slow growing and can survive for hundreds of years (Love et al., 2007; Roberts & Hirshfield, 2003), recovery from damage could take many years. Corals that occur in association with shallow-water coral reefs are protected by Executive Order 13089, Coral Reef Protection, and managed by the Coral Reef Task Force (Executive Order 13089: Coral Reef Protection, 63 *Federal Register* 32701–32703 [June 16, 1998]). The Navy is the Department of Defense representative to the United States Coral Reef Task Force and also carries out the Coral Reef Protection Implementation Plan (Lobel & Lobel, 2000).

Deep-water corals are azooxanthellate (lack symbiotic algae) and thus do not form consolidated biogenic substrate, but rather form mounds of intermediate substrate over hard bottom areas. Deep-water coral taxa in the Study Area consist primarily of hexacorals (stony corals, black corals, and gold corals), octocorals (e.g., true soft corals, gorgonians, sea pens), and hydrocorals (e.g., lace corals) (Hourigan et al., 2017a). Deep-water corals are widely distributed throughout the United States Pacific Island region, including the Hawaiian Archipelago (Parrish et al., 2015). In general, deep corals in the Hawaii region do not form the extensive three-dimensional reef structures observed in the Atlantic and South Pacific. Octocorals and antipatharians (black corals) have been found in high densities at numerous sites, particularly on topographically high areas. Deep-sea coral communities are prevalent throughout the entire Hawaiian Archipelago (Etnoyer & Morgan, 2003) and have been found at all depths investigated (maximum of about 1,800 m) where suitable substrate exists (Baco, 2007). Approximately 200 species of deep corals (octocorals, antipatharians, and zoanthids) have been found in the Hawaiian Archipelago region (Parrish & Baco, 2007; Parrish et al., 2015). Precious corals, black corals, and various octocoral species appear to be the most numerous deep-water corals at depths less than about 600 m, while octocorals dominate below 600 m (Parrish et al., 2015). Study results indicate that stony corals are relatively rare at all depths and that most species are solitary (non-colonial). Gorgonians are the most common group of deep-sea corals in the Hawaiian Islands.

Most of the habitat-forming deep-sea corals in the Southern California portion of the Study Area are anthozoans and hydrozoans (Etnoyer & Morgan, 2003; Etnoyer & Morgan, 2005). Deep-water corals have been documented throughout the Southern California Bight (generally considered to be the area between Point Conception and San Diego, California), although the corals appear to be more restricted in the region near San Diego. Deep-water areas off the California coast, including the Channel Islands National Marine Sanctuary, support numerous corals such as sea fans (gorgonians), *Lophelia pertusa*, scleractinians such as the cup coral *Caryophyllia arnoldi*, and black corals (National Oceanic and Atmospheric Administration Fisheries & Southwest Fisheries Science Center, 2010; Whitmire & Clarke, 2007). At least 26 taxa of deep corals were recorded at a site within the Channel Islands sanctuary (Clarke et al., 2015). Large populations of hydrocorals occur at Tanner, Cortes, and Farnsworth Banks, offshore of southern California (Southern California Marine Institute, 2016). Much of the rocky area of Farnsworth Bank to depths of 66 m was found to be covered by the hydrocoral *Stylaster californicus* (Clarke et al., 2015). Surveys of a rocky bank south of Anacapa Island (depths of 97 to 314 m) found gorgonians and the black coral *A. dendrochristos* to be relatively abundant. Additional surveys of a nearby bank at depths of 275 to 900 m documented numerous corals, primarily including *A. dendrochristos*, the soft mushroom coral *Heteropolypus ritteri*, several sea fan species, *L. pertusa*, the cup coral *Desmophyllum dianthus*, and the sea pen *Halipteris californica* (on soft sediment only). Numerous species, including gold coral species, have been documented during various other surveys of banks off southern California.

The greatest threat to deep-water coral is physical strike and disturbance resulting from human activities. Deep corals are susceptible to physical disturbance due to the branching and fragile growth form of some species, slow growth rate (colonies can be hundreds of years old), and low reproduction and recruitment rates. Fishing activities, particularly trawling, are the primary threats to deep corals (Boland et al., 2016; Hourigan et al., 2017b; Packer et al., 2017; Rooper et al., 2016; Yoklavich et al., 2017). Marine debris is also a potential threat. For example, during one study in the Atlantic Ocean, a fishing trap, fishing line, balloon remnants, and ribbon was observed either lying on or wrapped around deep-sea corals located off the northeastern United States (Quattrini et al., 2015). Other potential human-caused threats to deep-water corals include coral harvesting (e.g., black corals), hydrocarbon exploration and extraction, cable and pipeline installation, and other bottom-disturbing activities (Boland et al., 2016; Clarke et al., 2015; Parrish et al., 2015). Natural threats consist of sedimentation and bioerosion of the substrate.

3.4.2.3.4 Flatworms (Phylum Platyhelminthes)

Flatworms include between 12,000 and 20,000 marine species worldwide (World Register of Marine Species Editorial Board, 2015) and are the simplest form of marine worm (Castro & Huber, 2000b). The largest single group of flatworms are parasites commonly found in fishes, seabirds, and marine mammals (Castro & Huber, 2000b; University of California Berkeley, 2010b). The life history of parasitic flatworms plays a role in the regulation of populations of the marine vertebrates they inhabit. Ingestion by the host organism is the primary dispersal method for parasitic flatworms. Parasitic forms are not typically found in the water column outside of a host organism. The remaining groups are non-parasitic carnivores, living without a host. Flatworms are found throughout the Study Area living on rocks in tide pools and reefs, or within the top layer of sandy areas. Dominant genera of flatworms in the Insular Pacific-Hawaiian Large Marine Ecosystem include *Pseudobiceros* and *Pseudoceros*. Flatworms in the genera *Waminoa* and *Freemania* occur in the waters around the California Current Large Marine Ecosystems. Several species of wrasses and other reef fish prey on flatworms (Castro & Huber, 2000a, 2000b).

3.4.2.3.5 Ribbon Worms (Phylum Nemertea)

Ribbon worms include over 1,300 marine species worldwide (World Register of Marine Species Editorial Board, 2015). Ribbon worms, with their distinct gut and mouth parts, are more complex than flatworms (Castro & Huber, 2000b). A unique feature of ribbon worms is the extendable proboscis (an elongated, tubular mouth part), which can be ejected to capture prey, to aid in movement, or for defense (Brusca & Brusca, 2003). Most ribbon worms are active, bottom-dwelling predators of small invertebrates such as annelid worms and crustaceans (Brusca & Brusca, 2003; Castro & Huber, 2000b). Some are scavengers or symbiotic (parasites or commensals). Some ribbon worms are pelagic, with approximately 100 pelagic species identified from all oceans (Roe & Norenburg, 1999). Pelagic species generally drift or slowly swim by undulating the body. Ribbon worms exhibit a variety of reproductive strategies, including direct development with juveniles hatching from egg cases and indirect development from planktonic larvae (Brusca & Brusca, 2003). In addition, many species are capable of asexual budding or regeneration from body fragments. Ribbon worms have a relatively small number of predators, including some birds, fishes, crabs, molluscs, squid, and other ribbon worms (McDermott, 2001). Ribbon worms are found throughout the Study Area. They occur in most marine environments, although usually in low abundances. They occur in embayments; soft, intermediate, and rocky shores and subtidal habitats of coastal waters; and deep-sea habitats. Some are associated with biotic habitats such as mussel clumps, coral reefs, kelp holdfasts, seagrass beds, and worm burrows (Thiel & Kruse, 2001). Approximately 10 species of ribbon worms from the classes *Anopla* and *Enopla* are known from Hawaii (Hawaiisfishes, 2017), and a total of 64 species have been identified in intertidal habitats of California (Bernhardt, 1979).

3.4.2.3.6 Round Worms (Phylum Nematoda)

Round worms include over 7,000 marine species (World Register of Marine Species Editorial Board, 2015). Round worms are small and cylindrical, abundant in sediment habitats such as soft to intermediate shores and soft to intermediate bottoms, and also found in host organisms as parasites (Castro & Huber, 2000b). Round worms are some of the most widespread marine invertebrates, with population densities of up to 1 million or more organisms per square meter of sediment (Levinton, 2009). This group has a variety of food preferences, including algae, small invertebrates, annelid worms, and organic material from sediment. Like parasitic flatworms, parasitic nematodes play a role in regulating populations of other marine organisms by causing illness or mortality. Species in the family Anisakidae infect marine fish, and may cause illness in humans if fish are consumed raw without proper precautions (Castro & Huber, 2000b). Round worms are found throughout the Study Area.

3.4.2.3.7 Segmented Worms (Phylum Annelida)

Segmented worms include approximately 14,000 currently accepted marine species worldwide in the phylum Annelida, although the number of potentially identified marine species is nearly 25,000 (World Register of Marine Species Editorial Board, 2015). Most marine annelids are in the class Polychaeta. Polychaetes are the most complex group of marine worms, with a well-developed respiratory and gastrointestinal system (Castro & Huber, 2000b). Different species of segmented worms may be highly mobile or burrow in the bottom (soft to intermediate shore or bottom habitats) (Castro & Huber, 2000b). Polychaete worms exhibit a variety of life styles and feeding strategies, and may be predators, scavengers, deposit-feeders, filter-feeders, or suspension feeders (Jumars et al., 2015). The variety of feeding strategies and close connection to the bottom make annelids an integral part of the marine food web (Levinton, 2009). Burrowing and agitating the sediment increases the oxygen content of bottom sediments and makes important buried nutrients available to other organisms. This allows bacteria and other organisms, which are also an important part of the food web, to flourish on the bottom. Benthic polychaetes also vary in their mobility, including sessile attached or tube-dwelling worms, sediment burrowing worms, and mobile surface or subsurface worms. Some polychaetes are commensal or parasitic. Many polychaetes have planktonic larvae.

Polychaetes are found throughout the Study Area inhabiting rocky, sandy, and muddy areas of the bottom, vegetated habitats, and artificial substrates. Some are associated with biotic habitats such as mussel clumps, coral reefs, and worm burrows. Some species of worms build rigid (e.g., *Diopatra* spp.) or sand-encrusted (*Phragmatapoma* spp.) tubes, and aggregations of these tubes form a structural habitat. Giant tube worms (*Riftia pachyptila*) are chemosynthetic (using a primary production process without sunlight) reef-forming worms living on hydrothermal vents of the abyssal oceans. Their distribution is poorly known in the Study Area. A total of 20 taxa of annelid worms were documented at intertidal locations of Oahu, compared to 71 taxa in central California (Zabin et al., 2013).

3.4.2.3.8 Bryozoans (Phylum Bryozoa)

Bryozoans include approximately 6,000 marine species worldwide (World Register of Marine Species Editorial Board, 2015). They are small box-like, colony-forming animals that make up the “lace corals.” Colonies can be encrusting, branching, or free-living. Bryozoans may form habitat similar in complexity to sponges (Buhl-Mortensen et al., 2010). Bryozoans attach to a variety of surfaces, including intermediate and hard bottom, artificial structures, and algae, and feed on particles suspended in the water (Hoover, 1998b; Pearse et al., 1987; University of California Berkeley, 2010d). Bryozoans are of economic importance for bioprospecting (the search for organisms for potential commercial use in pharmaceuticals). As common biofouling organisms, bryozoans also interfere with boat operations and clog industrial water intakes and conduits (Hoover, 1998b; Western Pacific Regional Fishery Management Council, 2001). Bryozoans occur throughout the Study Area but are not expected at depths beyond the continental slope (Ryland & Hayward, 1991). Habitat-forming species are most common on temperate continental shelves with relatively strong currents (Wood et al., 2012). Common species in the Insular Pacific-Hawaiian Large Marine Ecosystem are violet encrusting bryozoan (*Disporella violacea*) and lace bryozoan (*Reteporellina denticulata*). Species that occur in the California Current Large Marine Ecosystem include arborescent bryozoans of the genus *Bugula* and encrusting bryozoans of the genus *Schizoporella*.

3.4.2.3.9 Squid, Bivalves, Sea Snails, Chitons (Phylum Mollusca)

The phylum Mollusca includes approximately 45,000 marine species worldwide (World Register of Marine Species Editorial Board, 2015). These organisms occur throughout the Study Area, including open ocean areas, at all depths. Sea snails and slugs (gastropods), clams and mussels (bivalves), chitons (polyplacophorans), and octopus and squid (cephalopods) are examples of common molluscs in the Study Area. Snails and slugs occur in a variety of soft, intermediate, hard, and biogenic habitats. Chitons are typically found on hard bottom and artificial structures from the intertidal to littoral zone but may also be found in deeper water and on substrates such as aquatic plants. Many molluscs possess a muscular organ called a foot, which is used for mobility. Many molluscs also secrete an external shell

(Castro & Huber, 2000b), although some molluscs have an internal shell or no shell at all (National Oceanic and Atmospheric Administration Fisheries, 2015). Sea snails and slugs eat fleshy algae and a variety of invertebrates, including hydroids, sponges, sea urchins, worms, other snails, and small crustaceans, as well as detritus (Castro & Huber, 2000b; Colin & Arneson, 1995a; Hoover, 1998b). Clams, mussels, and other bivalves are filter feeders, ingesting suspended food particles (e.g., phytoplankton, detritus) (Castro & Huber, 2000b). Chitons, sea snails, and slugs use rasping tongues, known as radula, to scrape food (e.g., algae) off rocks or other hard surfaces (Castro & Huber, 2000b; Colin & Arneson, 1995a). Squid and octopus are active swimmers at all depths and use a beak to prey on a variety of organisms including fish, shrimp, and other invertebrates (Castro & Huber, 2000b; Hoover, 1998b; Western Pacific Regional Fishery Management Council, 2001). Octopuses mostly prey on fish, shrimp, eels, and crabs (Wood & Day, 2005).

Important commercial, ecological, and recreational species of molluscs in the Insular Pacific-Hawaiian Large Marine Ecosystem include: various species of squid, the endemic cuttlefish (*Euprymna scolopes*), bivalves (clams and mussels), and limpets (*Cellana exarata* and *Cellana sandwicensis*) (Western Pacific Regional Fishery Management Council, 2001). Important commercial, ecological, and recreational species of molluscs in the California Current Large Marine Ecosystem include multiple abalone species, California market squid (*Doryteuthis opalescens*) (Clark et al., 2005), keyhole limpet (*Megathura crenulata*), Kellet's whelk (*Kelletia kelletia*), various species of octopus, sea hare (*Aplysia* spp.), snails (*Lithopoma undosum*, *Tegula* spp.), and Pismo clam (*Tivela stultorum*). Only one species of abalone, the red abalone (*Haliotis rufescens*), is currently fished recreationally, north of San Francisco County. The abalone fishery is closed to all commercial fishing. Black abalone and white abalone are listed under the ESA (see Section 3.4.2.2.1, Black Abalone [*Haliotis cracherodii*], and Section 3.4.2.2.2, White Abalone [*Haliotis sorenseni*]), while the green abalone (*Haliotis fulgens*) and pink abalone (*Haliotis corrugata*) are designated as species of concern.

3.4.2.3.10 Shrimp, Crab, Lobster, Barnacles, Copepods (Phylum Arthropoda)

Shrimp, crabs, lobsters, barnacles, and copepods are animals with an exoskeleton, which is a skeleton on the outside of the body (Castro & Huber, 2000b), and are classified as crustaceans in the Phylum Arthropoda. The exoskeletons are made of a polymer called chitin, similar to cellulose in plants, to which the animals add other compounds to achieve flexibility or hardness. There are over 57,000 marine arthropod species, with about 53,000 of these belonging to the subphylum Crustacea (World Register of Marine Species Editorial Board, 2015). These organisms occur throughout the Study Area at all depths. Crustaceans may be carnivores, omnivores, predators, or scavengers, preying on molluscs (primarily gastropods), other crustaceans, echinoderms, small fishes, algae, and seagrass (Waikiki Aquarium, 2009a, 2009b, 2009c; Western Pacific Regional Fishery Management Council, 2009). Barnacles and some copepods are filter feeders, extracting algae and small organisms from the water (Levinton, 2009). Copepods may also be parasitic, affecting most phyla of marine animals (Walter & Boxshall, 2017). As a group, arthropods occur in a wide variety of habitats. Shrimp, crabs, lobsters, and copepods may be associated with soft to hard substrates, artificial structures, and biogenic habitats. Barnacles inhabit hard and artificial substrates.

Important commercial, ecological, and recreational species of Crustacea in the Insular Pacific-Hawaiian Large Marine Ecosystem include several lobster species from the taxonomic groups Palinuridae (spiny lobsters) and Scyllaridae (slipper lobsters) (Western Pacific Regional Fishery Management Council, 2009). Lobsters occur primarily within the subtidal zone, although their range can extend slightly deeper. Most species occur throughout the tropical oceans of the world, while the endemic Hawaiian spiny lobster is found only in Hawaii and Johnston Atoll (Polovina et al., 1999). Important commercial, ecological, and recreational species of Crustacea in the California Current Large Marine Ecosystem include the spot shrimp (*Pandalus platyceros*), ridgeback rock shrimp (*Sicyonia ingentis*), rock crab (*Cancer* species), sheep crab (*Loxorhynchus grandis*), and California spiny lobster (Clark et al., 2005).

3.4.2.3.11 Sea Stars, Sea Urchins, Sea Cucumbers (Phylum Echinodermata)

Organisms in this phylum include over 7,000 marine species, such as sea stars, sea urchins, and sea cucumbers (World Register of Marine Species Editorial Board, 2015). Asteroids (e.g., sea stars), echinoids (e.g., sea urchins), holothuroids (e.g., sea cucumbers), ophiuroids (e.g., brittle stars and basket stars), and crinoids (e.g., feather stars and sea lilies) are symmetrical around the center axis of the body (Mah & Blake, 2012). Echinoderms occur at all depth ranges from the intertidal zone to the abyssal zone and are almost exclusively benthic, potentially found on all substrates and structures. Most echinoderms have separate sexes, but a few species of sea stars, sea cucumbers, and brittle stars have both male and female reproductive structures. Many species have external fertilization, releasing gametes into the water to produce planktonic larvae, but some brood their eggs and release free-swimming larvae (Mah & Blake, 2012; McMurray et al., 2012). Many echinoderms are either scavengers or predators on sessile organisms such as algae, stony corals, sponges, clams, and oysters. Some species, however, filter food particles from sand, mud, or water (Hoover, 1998a). Predators of echinoderms include a variety of fish species (e.g., triggerfish, eels, rays, sharks), crabs, shrimps, octopuses, birds, and other echinoderms (sea stars).

Echinoderms are found throughout the Study Area. Important commercial, ecological, and recreational species in the Insular Pacific-Hawaiian Large Marine Ecosystem include helmet urchin (*Colobocentrotus atratus*), burrowing sea urchin (*Echinometra mathaei*), sea cucumbers, and sea stars. The crown-of-thorns sea star (*Acanthaster planci*) is a carnivorous predator that feeds on coral polyps and can devastate coral reefs. In 1969, crown-of-thorns sea stars infested reefs off southern Molokai but did not cause extensive damage to living coral polyps of cauliflower coral (Gulko, 1998; Hoover, 1998b). Important commercial, ecological, and recreational species of echinoderms in the California Current Large Marine Ecosystem include California sea cucumbers (*Parastichopus californicus*), sea stars (*Pisaster* spp.), red sea urchin (*Strongylocentrotus franciscanus*), and purple sea urchin (*S. purpuratus*) (Clark et al., 2005). Beginning in 2013, large numbers of sea stars have died along the west coast of North America due to sea-star wasting disease (Hewson et al., 2014; Miner et al., 2018). The virus causing the disease has also been found in sea urchins and sea cucumbers, although mass die-offs have not been documented for these taxa.

3.4.3 Environmental Consequences

This section evaluates how and to what degree the activities described in Chapter 2 (Description of Proposed Action and Alternatives) potentially impact invertebrates known to occur within the Study Area. Table 2.6-1 through Table 2.6-5 present the proposed training and testing activity locations for each alternative (including number of activities). General characteristics of all Navy stressors were introduced in Section 3.0.3.3 (Identifying Stressors for Analysis), and living resources' general susceptibilities to stressors were introduced in Section 3.0.3.6 (Biological Resource Methods). The stressors vary in intensity, frequency, duration, and location within the Study Area. The stressors analyzed for invertebrates are:

- **Acoustics** (sonar and other transducers, air guns, pile driving, vessel noise, weapons noise)
- **Explosives** (explosions in water)

- **Energy** (in-water electromagnetic devices, high-energy lasers)
- **Physical disturbance and strikes** (vessels and in-water devices, military expended materials, seafloor devices, pile driving)
- **Entanglement** (wires and cables, decelerators/parachutes, biodegradable polymers)
- **Ingestion** (military expended materials - munitions, military expended materials other than munitions)
- **Secondary stressors** (impacts on habitat, impacts on prey availability)

The analysis includes consideration of the mitigation that the Navy will implement to avoid potential impacts on invertebrates from explosives, and physical disturbance and strikes.

3.4.3.1 Acoustic Stressors

Assessing whether sounds may disturb or injure an animal involves understanding the characteristics of the acoustic sources, the animals that may be near the sound, and the effects that sound may have on the physiology and behavior of those animals. Marine invertebrates are likely only sensitive to water particle motion caused by nearby low-frequency sources, and likely do not sense distant or mid- and high-frequency sounds (Section 3.4.2.1.3, Sound Sensing and Production). Compared to some other taxa of marine animals (e.g., fishes, marine mammals), little information is available on the potential impacts on marine invertebrates from exposure to sonar and other sound-producing activities (Hawkins et al., 2015). Historically, many studies focused on squid or crustaceans and the consequences of exposures to broadband impulsive air guns typically used for oil and gas exploration. More recent investigations have included additional taxa (e.g., molluscs) and sources, although extensive information is not available for all potential stressors and impact categories. The following Background sections discuss the currently available information on acoustic effects to marine invertebrates. These effects range from physical injury to behavioral or stress response. Aspects of acoustic stressors that are applicable to marine organisms in general are presented in Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities).

3.4.3.1.1 Background

A summary of available information related to each type of effect is presented in the following sections. Some researchers discuss effects in terms of the acoustic near field and far field. The near field is an area near a sound source where considerable interference between sound waves emerging from different parts of the source is present. Amplitude may vary widely at different points within this acoustically complex zone, and sound pressure and particle velocity are generally out of phase. The far field is the distance beyond which sound pressure and particle velocity are in phase, all sound waves appear to originate from a single point, and pressure levels decrease predictably with distance. The boundary between the near and far field is frequency-dependent, with the near field extending farther at lower frequencies. It has been estimated that the near field for a sound of 500 Hz (intensity not specified) would extend about 3 m from the source (Myrberg, 2001).

3.4.3.1.1.1 Injury

Injury refers to the direct effects on the tissues or organs of an animal due to exposure to pressure waves or particle motion. Available information on injury to invertebrates resulting from acoustic sources pertains mostly to damage to the statocyst, an organ sensitive to water particle motion and responsible for balance and orientation in some invertebrates. A few studies have also investigated effects to appendages and other organs, and one study investigated zooplankton mortality in response to air gun firing.

Researchers have investigated the effects of noise on American lobsters exposed to air gun firings in an aquarium and in the field (Payne et al., 2007). Lobsters in the aquarium were placed about 3.5 m from the air guns and exposed to sound levels of about 200 dB (peak-to-peak). Caged lobsters in the field were located 2 m from the air guns and exposed to higher-intensity sound levels (about 230 dB peak-to-peak). No physical damage to appendages and no effects on balance or orientation (indicating no damage to statocysts) were observed in any lobsters. No visible evidence of damage to hepatopancreata (digestive glands) or ovaries were found. Caged snow crabs (*Chionoecetes opilio*) were exposed to repeated air gun firings in the field (Christian et al., 2003). Crabs exposed to a single air gun were placed at depths of 2 to 15 m, while crabs exposed to air gun arrays were placed at depths of 4 to 170 m. Air guns were fired during multiple sessions, with each session consisting of a firing every 10 seconds for 33 minutes. Peak received levels were up to 207 dB re 1 μPa and 187 decibels referenced to 1 squared micropascal (dB re 1 μPa^2) (single gun), and 237 dB re 1 μPa and 175 dB re 1 μPa^2 (array). Post-experimental examination showed no physical damage to statocysts, hepatopancreata, heart muscle or surrounding tissue, carapace, or appendages. As a comparison, air guns operated at full capacity during Navy activities would produce an SPL of approximately 206 dB re 1 μPa rms and a sound exposure level (SEL) of 185 to 196 decibels referenced to 1 micropascal squared per second (dB re 1 μPa^2-s) at a distance 1 m from the air gun. Air guns are also operated at less than full capacity, resulting in reduced sound levels.

In three instances, seismic air gun use has been hypothesized as the cause of giant squid strandings. This was based on the proximity in time and space of the squid and operating seismic vessels and, in two of the events, to physical injuries considered consistent with exposure to impulsive acoustic waves (Guerra et al., 2004; Guerra & Gonzales, 2006; Leite et al., 2016). However, because the animals were not observed at the time of potential impact, the cause(s) of the injuries and strandings cannot be determined conclusively.

Zooplankton abundance and mortality was investigated in the context of exposure to air gun firings in an open ocean environment (McCauley et al., 2017). Net tows and sonar surveys were conducted after transects involving air gun firings were completed. The results indicated decreased zooplankton abundance and increased mortality as a result of exposure. The most abundant organisms (copepods and cladocerans [water fleas]) showed a 50 percent decrease in abundance at distances of about 500 to 700 m from the source. Received noise level at this distance was about 156 dB re 1 μPa^2-s SEL and 183 dB re 1 μPa peak-to-peak. There was no effect on the abundance of these specific taxa at distances of about 1 kilometer (km) from the source (153 dB re 1 μPa^2-s SEL and 178 dB re 1 μPa peak-to-peak). However, an overall decrease in zooplankton abundance was reported at distances to about 1.2 km from the source. The authors speculated that the effects could have been caused by damage to external sensory hairs on the organisms.

Physiological studies of wild captured cephalopods found progressive damage to statocysts in squid and octopus species after exposure to 2 hours of low-frequency (50 to 400 Hz) sweeps (100 percent duty cycle) at SPL of 157 to 175 dB re 1 μPa (André et al., 2011; Sole et al., 2013). It is noted that the animals were in the near field (distance was not specified in the report, but animals were likely within a few to several feet of the sound source based on the experiment description) where there is significant particle motion. In a similar experiment designed to control for possible confounding effects of experimental tank walls, common cuttlefish (*Sepia officinalis*) were exposed to 2 hours of low-frequency sweeps (100 to 400 Hz; 100 percent duty cycle with a 1-second sweep period) in an offshore environment (Sole et al., 2017). Sounds were produced by a transducer located near the surface, and caged experimental animals were placed at depths between 7 and 17 m. Received sound levels ranged from 139 to 142 dB re 1 μPa^2. Maximum particle motion of 0.7 meter per squared second was recorded at the cage nearest the transducer (7.1 m between source and cage). Progressive damage to sensory hair cells of the statocysts were found immediately after and 48 hours after sound exposure, with the severity of effects being proportional to distance from the transducer. The authors suggest that whole-body vibrations resulting from particle motion were transmitted to the statocysts, causing damage to the structures. Statocyst damage was also found in captive individuals of two jellyfish species (Mediterranean jellyfish [*Cotylorhiza tuberculata*] and barrel jellyfish [*Rhizostoma pulmo*]) under the same exposure parameters (50 to 400 Hz sweeps; 2-hour exposure time; 100 percent duty cycle with a 1-second sweep period; approximately 157 to 175 dB re 1 µPa received SPL) (Sole et al., 2016). In the context of overall invertebrate population numbers, most individuals exposed to acoustic stressors would be in the far field where particle motion would not occur and, therefore, the types of damage described above would not be expected. In addition, exposure duration would be substantially less than 2 hours.

This limited information suggests that the potential for statocyst damage may differ according to the type of sound (impulsive or continuous) or among invertebrate taxa (e.g., crustaceans and cephalopods). Therefore, a definitive conclusion regarding potential impacts on invertebrates in general is unsupported. Although invertebrate occurrence varies based on location, depth, season, and time of day (for example, the rising of the deep scattering layer, which consists of numerous invertebrate taxa), individuals could be present in the vicinity of impulsive or non-impulsive sounds produced by Navy activities. Estimation of invertebrate abundance at any particular location would generally not be feasible, but there is a general pattern of higher abundances in relatively productive estuarine and nearshore waters compared to abundances in offshore portions of the Study Area. The number of individuals affected would be influenced by sound sensing capabilities. As discussed in Section 3.4.2.1.3 (Sound Sensing and Production), invertebrate acoustic sensing is probably limited to the particle motion component of sound. Water particle motion is most detectable near a sound source and at lower frequencies, which likely limits the range at which invertebrates can detect sound.

3.4.3.1.1.2 Physiological Stress

A stress response consists of one or more physiological changes (e.g., production of certain hormones) that help an organism cope with a stressor. However, if the magnitude or duration of the stress response is too great or too prolonged, there can be negative consequences to the organism. Physiological stress is typically evaluated by measuring the levels of relevant biochemicals in the subject organisms.

The results of two investigations of physiological stress in adult invertebrates caused by impulsive noise varied by species. Some biochemical stress markers and changes in osmoregulation were observed in American lobsters exposed to air gun firings at distances of approximately 2 to 4 m from the source (Payne et al., 2007). Increased deposits of carbohydrates, suggesting a possible stress response, were noted in digestive gland cells 4 months after exposure. Conversely, repeated air gun exposures caused no changes in biochemical stress markers in snow crabs located from 2 to 170 m from the source (Christian et al., 2003).

Several investigations of physiological reactions of captive adult invertebrates exposed to boat noise playback and other continuous noise have been conducted. Continuous exposure to boat noise playback resulted in changes to some biochemical levels indicating stress in common prawns (*Palaemon serratus*) (30-minute exposure to sound levels of 100 to 140 dB re 1 µPa rms) and European spiny lobsters

(30-minute exposure to sound levels up to 125 dB re 1μPa rms) (Celi et al., 2015; Filiciotto et al., 2014; Filiciotto et al., 2016). Increased oxygen consumption, potentially indicating stress, was found in shore crabs exposed to ship-noise playback of 148 to 155 dB re 1 μPa for 15 minutes (Wale et al., 2013a). Red swamp crayfish (*Procambarus clarkii*) exposed to 30-minute continuous acoustic sweeps (frequency range of 0.1 to 25 kHz, peak amplitude of 148 dB rms at 12 kHz) showed changes in some biochemical levels indicating stress (Celi et al., 2013). Captive sand shrimp (*Crangon crangon*) exposed to low-frequency noise (30 to 40 dB above ambient) continuously for 3 months demonstrated decreases in growth rate and reproductive rate (Lagardère, 1982). Mediterranean mussels (*Mytilus galloprovincialis*) exposed to 30-minute continuous acoustic sweeps (frequency range of 0.1 to 60 kHz, maximum SPL of 150 dB rms re 1 μPa), although exhibiting no behavioral changes at any tested frequency, showed statistically significant increases in some biochemical stress indicators (e.g., glucose and heat shock protein) in the low-frequency exposure category (0.1 to 5 kHz) (Vazzana et al., 2016). Changes in glucose levels were found in blue crabs (*Callinectes sapidus*) exposed to low-frequency sound (broadband noise with a significant component of 60 Hz at approximately 170 dB re 1 μPa SPL) and mid-frequency pulsed tones and chirps (1.7 to 4 kHz at approximately 180 dB re 1 μPa SPL) (Dossot et al., 2017).

In addition to experiments on adult invertebrates, some studies have investigated the effects of impulsive and non-impulsive noise (air guns, boat noise, turbine noise) on invertebrate eggs and larvae. Data on similar effects resulting from sonar are currently unavailable. Developmental delays and body malformations were reported in New Zealand scallop (*Pecten novaezelandiae*) larvae exposed to seismic air gun playbacks at frequencies of 20 Hz to 22 kHz with SPL of 160 to 164 dB re 1 μPa (Aguilar de Soto et al., 2013). Although uncertain, the authors suggested physiological stress as the cause of the effects. Larvae in the relatively small (2 m diameter) experimental tank were considered close enough to the acoustic source to experience particle motion, which would be unlikely at the same pressure levels in the far field. Playbacks occurred once every 3 seconds and the larvae were periodically examined over the course of 90 hours. Snow crab (*Chionoecetes opilio*) eggs located in 2 m water depth and exposed to repeated firings of a seismic air gun (peak received SPL was 201 dB re 1 μPa) had slightly increased mortality and apparent delayed development (Christian et al., 2003). However, Dungeness crab (*Metacarcinus magister*) zoeae were not affected by repeated exposures to an air gun array (maximum distance of about 62 ft. slant distance) (Pearson et al., 1994), and exposure of southern rock lobster (*Jasus edwardsii*) eggs to air gun SELs of up to 182 dB re 1 μPa^2-s did not result in embryonic developmental effects (Day et al., 2016). An investigation of the effects of boat noise playback on the sea hare (*Stylocheilus striatus*) found reduced embryo development and increased larvae mortality, but no effect on the rate of embryo development (Nedelec et al., 2014). Specimens were exposed to boat-noise playback for 45 seconds every 5 minutes over a 12-hour period. Continuous playback of simulated underwater tidal and wind turbine sounds resulted in delayed metamorphosis in estuarine crab larvae (*Austrohelice crassa* and *Hemigrapsus crenulatus*) that were observed for up to about 200 hours (Pine et al., 2016).

Overall, the results of these studies indicate the potential for physiological effects in some, but not all, adult invertebrates exposed to air guns near the source (about 2 to 4 m) and to boat and other continuous noise for durations of 15 to 30 minutes or longer. Larvae and egg development effects were reported for impulsive (distance from source of about 2 m) and non-impulsive noise exposures of extended duration (intermittently or continuously for several to many hours) and for air gun playback and field exposure, although air gun noise had no effect in one study. In general, exposure to continuous noise such as vessel operation during Navy training or testing events would occur over a shorter duration and sound sources would be more distant than those associated with most of the studies.

Adverse effects resulting from short exposure times have not been shown experimentally. A range to effects was not systematically investigated for air gun use. Experiments using playback of air gun and boat noise were conducted in relatively small tanks where particle motion, which decreases rapidly with distance, could have been significant. Marine invertebrate egg and larval abundances are high relative to the number of adults, and eggs and larvae are typically subject to high natural mortality rates. These factors decrease the likelihood of population-level effects resulting from impacts on eggs and larvae from physiological stress associated with Navy training and testing events.

3.4.3.1.1.3 Masking

Masking occurs when one sound interferes with the detection or recognition of another sound. Masking can limit the distance over which an organism can communicate or detect biologically relevant sounds. Masking can also potentially lead to behavioral changes.

Little is known about how marine invertebrates use sound in their environment. Some studies show that crab, lobster, oyster, and coral larvae and post-larvae may use nearby reef sounds when in their settlement phase. Orientation and movement toward reef sounds was found in larvae located at 60 to 80 m from a sound source in open water, and in experimental tanks (distance from the sound source was about 150 cm in one laboratory study) (Radford et al., 2007; Stanley et al., 2010; Vermeij et al., 2010). The component of reef sound used is generally unknown, but an investigation found that low-frequency sounds (200 to 1,000 Hz) produced by fish at dawn and dusk on a coral reef were the most likely sounds to be detectable a short distance from the reef (Kaplan & Mooney, 2016). Similarly, lobed star coral larvae were found to have increased settlement on reef areas with elevated sound levels, particularly in the frequency range of 25 to 1,000 Hz (Lillis et al., 2016). Mountainous star coral (*Orbicella faveolata*) larvae in their settlement phase were found to orient toward playbacks of reef sounds in an experimental setup, where received sound levels were about 145 to 149 dB re 1 µPa and particle velocity was about 9×10^{-8} meters per second (Vermeij et al., 2010). Marine invertebrates may also use sound to communicate and avoid predators (Popper et al., 2001). Crabs (*Panopeus* species) exposed to playback of predatory fish vocalizations reduced foraging activity, presumably to avoid predation risk (Hughes et al., 2014). The authors suggest that, due to lack of sensitivity to sound pressure, crabs are most likely to detect fish sounds when the fish are nearby. Anthropogenic sounds could mask important acoustic cues such as detection of settlement cues or predators, and potentially affect larval settlement patterns or survivability in highly modified acoustic environments (Simpson et al., 2011). Low-frequency sounds could interfere with perception of low-frequency rasps or rumbles among crustaceans, particularly when conspecific sounds are produced at the far end of the hearing radius. Navy activities occurring relatively far from shore would produce transient sounds potentially resulting in only intermittent, short-term masking, and would be unlikely to impact the same individuals within a short time. Training and testing activities would generally not occur at known reef sites within the probable reef detection range of larvae. Impacts could be more likely in locations where anthropogenic noise occurs frequently within the perceptive range of invertebrates (e.g., pierside locations in estuaries). There are likely many other non-Navy noise sources present in such areas, and potential impacts on invertebrates would be associated with all anthropogenic sources.

3.4.3.1.1.4 Behavioral Reactions

Behavioral reactions refer to alterations of natural behaviors due to exposure to sound. Most investigations involving invertebrate behavioral reactions have been conducted in relation to air gun use, pile driving, and vessel noise. Studies of air gun impacts on marine invertebrates (crustaceans and cephalopods) have typically been conducted with equipment used for seismic exploration, and the limited results suggest responses may vary among taxa. Snow crabs placed 48 m below a seismic air gun array did not react behaviorally to repeated firings (peak received SPL was 201 dB re 1 µPa) (Christian et al., 2003). Studies of commercial catch of rock lobsters (*Panulirus cygnus*) and multiple shrimp species in the vicinity of seismic prospecting showed no long-term adverse effects to catch yields, implying no detectable long-term impacts on abundance from intermittent anthropogenic sound exposure over long periods (Andriguetto-Filho et al., 2005; Parry & Gason, 2006). Conversely, squid have exhibited various behavioral reactions when exposed to impulsive noise such as air gun firing (McCauley et al., 2000). Some squid showed strong startle responses, including inking, when exposed to the first shot of broadband sound from a nearby seismic air gun (received SEL of 174 dB re 1 µPa rms) Strong startle response was not seen when sounds were gradually increased, but the squid exhibited alarm responses at levels above 156 dB re 1 µPa rms (McCauley et al., 2000). Southern reef squids (*Sepioteuthis australis*) exposed to air gun noise displayed alarm responses at levels above 147 dB re 1 μPa^2-s (Fewtrell & McCauley, 2012).

Pile driving produces sound pressure that moves through the water column and into the substrate, which may therefore affect both pelagic and benthic invertebrates. Impact pile driving produces a repetitive impulsive sound, while vibratory pile extraction produces a nearly continuous sound at a lower source level. Although few investigations have been conducted regarding impacts on invertebrates resulting from impact pile driving and extraction, the effects are likely similar to those resulting from other impulsive and vibrational (e.g., drilling) sources. When an underwater sound encounters the substrate, particle motion can be generated, resulting in vibration. Invertebrates may detect and respond to such vibrations. Playback of impact pile driving sound (137 to 152 dB re 1 µPa peak to peak) in the water column near chorusing snapping shrimp resulted in an increase in the snap number and amplitude (Spiga, 2016). When exposed to playback of broadband impulsive pile driving sound of 150 dB SEL, Japanese carpet shell clams (*Ruditapes philippinarum*) exhibited reduced activity and valve closing, while Norway lobsters (*Nephrops norvegicus*) repressed burying, bioirrigation, and locomotion activity (Solan et al., 2016). Brittlestars (*Amphiura filiformis*) included in the experiment exhibited no overall statistically detectable behavioral changes, although the authors note that a number of individuals exhibited changes in the amount of sediment reworking activity. Pacific oysters (*Magallana gigas*) exposed to 3-minute pure tones responded behaviorally (shell closure) to low-frequency sounds, primarily in the range of 10 to 200 Hz (Charifi et al., 2017). The oysters were most sensitive to sounds of 10 to 80 Hz at 122 dB rms re 1 µPa, with particle acceleration of 0.02 meter per squared second. Invertebrates exposed to vibrations of 5 to 410 Hz (which is a proxy for the effects of vibratory pile removal) at various particle acceleration amplitudes in the substrate of a holding tank for 8-second intervals exhibited behavioral reactions ranging from valve closure (common mussel [*Mytilus edulis*]) to antennae sweeping, changes in locomotion, and exiting the shell (common hermit crab [*Pagurus bernhardus*]) (Roberts et al., 2015; Roberts et al., 2016a). Sensitivity was greatest at 10 Hz and at particle acceleration of 0.1 m per squared second. The authors analyzed data on substrate acceleration produced by pile driving in a river and found levels that would be detectable by the hermit crabs at 17 and 34 m from the source. Measurements were not available for other distances or in marine environments. Similarly, underwater construction-related detonations of about 14-pound (lb.) charge weight (presumably in fresh water) resulted in substrate vibrations 297 m from the source that would likely be detected by crabs. Follow-up experiments showed that particle acceleration detection sensitivity in mussels and hermit crabs ranged from 0.06 to 0.55 meters per squared second (Roberts et al., 2016b). Subsequent semi-field experiments consisted of operating a small pile driver for 2-hour periods in an enclosed dock (90 m long by 18 m wide, water depth of 2 to 3 m, and sediment depth of

3 to 4 m). Vibration in the sediment propagated farther (up to 30 m) in shallower water than in deeper water (up to 15 m). The signal in the sediment was mostly below 100 Hz and primarily from 25 to 35 Hz. Experimental animals in the enclosed area exhibited behavioral (e.g., width of shell opening) and physiological (e.g., oxygen demand) responses as a result of exposure, although information such as distance from the pile driver and particle acceleration at specific locations was not provided.

Common prawns and European spiny lobsters exposed to 30 minutes of boat noise playback in frequencies of 200 Hz to 3 kHz (sound levels of approximately 100 to 140 dB SPL [prawns] and 75 to 125 dB SPL [lobsters]) showed behavioral responses including changes in movement velocity, and distance moved, as well as time spent inside a shelter (Filiciotto et al., 2014; Filiciotto et al., 2016). Common cuttlefish exposed to playback of underwater ferry engine noise for 3.5 minutes (maximum sound level of about 140 dB re 1 µPa SPL) changed color more frequently, swam more, and raised their tentacles more often than control specimens or individuals exposed to playback of wave sounds (Kunc et al., 2014). Shore crabs (*Carcinus maenas*) exposed to ship noise playback did not exhibit changes in the ability or time required to find food, but feeding was often suspended during the playback (Wale et al., 2013b). Japanese carpet shell clams and Norway lobsters exposed to playback of ship noise for 7 days at received levels of 135 to 140 dB re 1 µPa exhibited reactions such as reduced activity, movement, and valve closing (Solan et al., 2016). Brittlestars (*A. filiformis*) included in the study showed no overall statistically detectable behavioral changes, although individual animals were affected. Antarctic krill (*Euphausia superba*) did not respond to a research vessel approaching at 2.7 knots (source level below 150 dB re 1 µPa) (Brierley et al., 2003). Decreased activity levels were found in blue crabs exposed to low-frequency broadband sound with a significant component of 60 Hz (approximately 170 dB re 1 µPa SPL) and mid-frequency pulsed tones and chirps (1.7 to 4 kHz at approximately 180 dB re 1 µPa SPL) (Dossot et al., 2017). Exposure to low-frequency sounds resulted in more pronounced effects than exposure to mid-frequency sounds. American lobsters appeared to be less affected than crabs.

A limited number of studies have investigated behavioral reactions to non-impulsive noise other than that produced by vessels. Red swamp crayfish (*Procambarus clarkii*) exposed to 30-minute continuous acoustic sweeps (frequency range of 0.1 to 25 kHz, peak amplitude of 148 dB rms at 12 kHz) exhibited changes in social behaviors (Celi et al., 2013). Caribbean hermit crabs (*Coenobita clypeatus*) delayed reaction to an approaching visual threat when exposed to continuous noise (Chan et al., 2010a; Chan et al., 2010b). The delay potentially put them at increased risk of predation, although the studies did not address possible simultaneous distraction of predators. Razor clams (*Sinonovacula constricta*) exposed to white noise and sine waves of 500 and 1,000 Hz responded by digging at a sound level of about 100 dB re 1 µPa (presumably as a defense reaction) but did not respond to sound levels of 80 dB re 1 µPa (Peng et al., 2016). Mediterranean mussels exposed to 30-minute continuous acoustic sweeps (frequency range of 0.1 to 60 kHz, maximum SPL of 150 dB rms re 1 µPa) showed no statistically significant behavioral changes compared to control organisms (Vazzana et al., 2016).

The results of these studies indicate that at least some invertebrate taxa would respond behaviorally to various levels of sound and substrate vibration produced within their detection capability. Comprehensive investigations of the range to effects of different sound and vibration sources and levels are not available. However, sound source levels for Navy pile diving and air gun use are within the range of received levels that have caused behavioral effects in some species (Solan et al., 2016). The low-frequency component of vessel noise would likely be detected by some invertebrates, although the number of individuals affected would be limited to those near enough to a source to experience particle motion.

3.4.3.1.2 Impacts from Sonar and Other Transducers

Many non-impulsive sounds associated with training and testing activities are produced by sonar. Other transducers include items such as acoustic projectors and countermeasure devices. Most marine invertebrates do not have the capability to sense sound pressure; however, some are sensitive to nearby low-frequency sounds, such as could be approximated by some low-frequency sonars. As described in Section 3.4.2.1.3 (Sound Sensing and Production), invertebrate species detect sound through particle motion, which diminishes rapidly with distance from the sound source. Therefore, the distance at which they may detect a sound is probably limited. Most activities using sonar or other transducers would be conducted in deep-water, offshore portions of the Study Area and are not likely to affect most benthic invertebrate species (including ESA-listed abalone species), although invertebrates in the water column could be affected. However, portions of the range complexes overlap nearshore waters of the continental shelf, and it is possible that sonar and other transducers could be used and affect benthic invertebrates in these areas. Sonar is also used in shallow water during pierside testing and maintenance testing.

Invertebrate species generally have their greatest sensitivity to sound below 1 to 3 kHz (Kunc et al., 2016) and would therefore not be capable of detecting mid- or high-frequency sounds, including the majority of sonars, or distant sounds in the Study Area. Studies of the effects of continuous noise such as boat noise, acoustic sweeps, and tidal/wind turbine sound (information specific to sonar use was not available) on invertebrates have found statocyst damage, elevated levels of biochemicals indicative of stress, changes in larval development, masking, and behavioral reactions under experimental conditions (see Section 3.4.3.1.1, Background). Noise exposure in the studies generally lasted from a few minutes to 30 minutes. The direct applicability of these results is uncertain because the duration of sound exposure in many of the studies is greater than that expected to occur during Navy activities, and factors such as environmental conditions (captive versus wild conditions) may affect individual responses (Celi et al., 2013). Individuals of species potentially susceptible to statocyst damage (e.g., some cephalopods) could be physically affected by nearby noise. Available research has shown statocyst damage to occur after relatively long-duration exposures (2 hours), which would be unlikely to occur to individual invertebrates due to transiting sources and potential invertebrate movement. An exception is pierside sonar testing and maintenance testing, where invertebrates (particularly sessile or slow-moving taxa such as bivalve molluscs, hydroids, and marine worms) could be exposed to sound for longer time periods compared to at-sea activities. Some studies also indicate the potential for impacts on invertebrate larval development resulting from exposure to non-impulsive noise (continuous or intermittent exposures over time periods of 12 to 200 hours) although, similar to stress effects, sonar has not been studied specifically. Masking could affect behaviors such as larvae settlement, communication, predator avoidance, and foraging in mollusc, crustacean, and coral species.

3.4.3.1.2.1 Impacts from Sonar and Other Transducers Under Alternative 1

Impacts from Sonar and Other Transducers Under Alternative 1 for Training Activities

Under Alternative 1, marine invertebrates would be exposed to low-, mid-, and high-frequency sonar and sound produced by other transducers during training activities. These activities could occur throughout the Study Area. The locations and number of activities proposed for training under

Alternative 1 are shown in Table 2.6-1 of Chapter 2 (Description of Proposed Action and Alternatives). Sounds produced during training are described in Section 3.0.3.3.1.1 (Sonar and Other Transducers).

Invertebrates would likely only sense low-frequency sonar or the low-frequency component of nearby sounds associated with other transducers. Sonar and other transducers are often operated in deep water, where impacts would be more likely for pelagic species than for benthic species. Only individuals within a short distance (potentially a few feet) of the most intense sound levels would experience impacts on sensory structures such as statocysts. Any marine invertebrate that detects low-frequency sound produced during training activities may alter its behavior (e.g., change swim speed, move away from the sound, or change the type or level of activity). Given the limited distance to which marine invertebrates are sensitive to sound, only a small number of individuals relative to overall population sizes would likely have the potential to be impacted. Because the distance over which most marine invertebrates are expected to detect any sounds is limited and because most sound sources are transient or intermittent (or both), any physiological effects, masking, or behavioral responses would be short term and brief. Without prolonged exposures to nearby sound sources, adverse impacts on individual invertebrates are not expected, and there would be no effects at the population level. Sonar and other sounds may result in brief, intermittent impacts on individual marine invertebrates and groups of marine invertebrates close to a sound source, but they are unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

Training activities using sonar or other transducers would not occur in designated black abalone critical habitat. In addition, sound associated with training activities would not affect essential biological features of critical habitat, which consist of adequate substrate, food availability, and water quality and circulation patterns. Critical habitat is not designated for white abalone under ESA. Due to the limited range of sound detection and infrequent use of sonar in relatively shallow waters where abalone species occur, physiological or behavioral reactions due to sonar exposure are unlikely. Pursuant to the ESA, the use of sonar and other transducers during training activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Sonar and Other Transducers Under Alternative 1 for Testing Activities

Under Alternative 1, marine invertebrates could be exposed to low-, mid-, and high-frequency acoustic sources during testing activities. Testing activities using sonar and other transducers could occur across the Study Area. Pierside testing of active sonar would continue in Pearl Harbor and San Diego Bay. The locations and number of activities proposed for testing under Alternative 1 are shown in Table 2.6-2 through Table 2.6-5 of Chapter 2 (Description of Proposed Action and Alternatives). Sounds produced during testing are described in Section 3.0.3.3.1.1 (Sonar and Other Transducers).

Invertebrates would likely only sense low-frequency sonar or the low-frequency component of nearby sounds associated with other transducers. Sonar and other transducers are often operated in deep water, where impacts would be more likely for pelagic species than for benthic species. Only individuals within a short distance (potentially a few feet) of the most intense sound levels would experience impacts on sensory structures such as statocysts. Any marine invertebrate that senses nearby or low-frequency sounds could react behaviorally. However, given the limited distance to which marine invertebrates are sensitive to sound, only a small number of individuals would likely be impacted. With the exception of pierside sonar testing, most sound sources are transient, and any physiological or behavioral responses or masking would be short term and brief. During pierside testing, invertebrates could be exposed to sound for longer time periods compared to at-sea testing. Pierside testing events generally occur over several hours of intermittent use. Sessile species or species with limited mobility located near pierside activities would be exposed multiple times. Species with greater mobility could potentially be exposed multiple times, depending on the time between testing events and the activity of individual animals. The limited information available suggests that sessile marine invertebrates repeatedly exposed to sound could experience physiological stress or react behaviorally (e.g., shell closing). However, recent survey work by the Virginia Institute of Marine Science suggests large populations of oysters inhabit Navy piers in the Chesapeake Bay that have persisted despite a history of sonar use in the area (Horton, 2016). In general, during use of sonar and other transducers, impacts would be more likely for sessile or limited-mobility taxa (e.g., sponges, bivalve molluscs, and echinoderms) than for mobile species (e.g., squids). Overall, given the limited distance to which marine invertebrates are sensitive to sound and the transient or intermittent nature (or both) of most sound sources, sonar and other sounds may result in brief, intermittent impacts on individual marine invertebrates and groups of marine invertebrates close to a sound source. The number of individuals affected would likely be small relative to overall population sizes. Sonar and other sounds are unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

Testing activities using sonar or other transducers would not occur in designated black abalone critical habitat. In addition, sound associated with training activities would not affect essential biological features of critical habitat, which consist of adequate substrate, food availability, and water quality and circulation patterns. Due to the limited range of sound detection and infrequent use of sonar in relatively shallow waters where abalone species occur, physiological or behavioral reactions due to sonar exposure are unlikely. Pursuant to the ESA, the use of sonar and other transducers during testing activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.1.2.2 Impacts from Sonar and Other Transducers Under Alternative 2

Impacts from Sonar and Other Transducers Under Alternative 2 for Training Activities

Under Alternative 2, marine invertebrates would be exposed to low-, mid-, and high-frequency sonar and sound produced by other transducers during training activities. The location of training activities would be the same as those described for Alternative 1, and are shown in Table 2.6-1 of Chapter 2 (Description of Proposed Action and Alternatives). Sounds produced during training are described in Section 3.0.3.3.1.1 (Sonar and Other Transducers).

Potential impacts on invertebrates would be similar to those discussed for training activities under Alternative 1. The only difference between Alternatives 1 and 2 in sonar and other transducer use is that the number of sonar hours used would be greater under Alternative 2 (Table 3.0-1). While the types of expected impacts on any individual invertebrate or group of invertebrates capable of detecting sonar or other sounds produced during training activities would remain the same, more animals would likely be affected. In the context of overall invertebrate population sizes and vertical distribution (benthic versus pelagic) within training areas, few individuals of any species would be close enough to the most intense sound level to experience impacts on sensory structures such as statocysts. Sonar and other sounds could result in stress, masking, or behavioral effects to marine invertebrates occurring close to a sound source. These exposures would generally be short term and brief, and a small number of individuals would be affected relative to overall population sizes. Physiological or behavioral effects resulting from sonar and other sounds are unlikely to impact survival, growth, recruitment, or reproduction of invertebrate populations or subpopulations.

Training activities using sonar or other transducers would not occur in designated black abalone critical habitat. In addition, sound associated with training activities would not affect essential biological features of critical habitat, which consist of adequate substrate, food availability, and water quality and circulation patterns. Due to the limited range of sound detection and infrequent use of sonar in relatively shallow waters where abalone species occur, physiological or behavioral reactions due to sonar exposure are unlikely. Pursuant to the ESA, the use of sonar and other transducers during training activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Sonar and Other Transducers Under Alternative 2 for Testing Activities

Under Alternative 2, marine invertebrates would be exposed to low-, mid-, and high-frequency acoustic sources during testing activities. The location of testing activities using sonar and other transducers would be the same as those described for Alternative 1 and are shown in Table 2.6-2 through Table 2.6-5 of Chapter 2 (Description of Proposed Action and Alternatives). Sounds produced during testing are described in Section 3.0.3.3.1.1 (Sonar and Other Transducers).

Potential impacts on invertebrates would be similar to those discussed for testing activities under Alternative 1. The only difference between Alternatives 1 and 2 in sonar and other transducer use is that the number of sonar hours used would be greater under Alternative 2 (Table 3.0-1). Increased use would occur for low-, mid-, and high-frequency sonars. Mid-frequency and high-frequency sonars are probably outside the detection capability of most marine invertebrates. While the types of expected impacts on any individual invertebrate or group of invertebrates capable of detecting sonar or other sounds produced during testing activities would remain the same, more animals would likely be affected. In the context of overall invertebrate population sizes and vertical distribution (benthic versus pelagic) within testing areas, few individuals of any species would be close enough to the most intense sound level to experience impacts on sensory structures such as statocysts. Sonar and other sounds could result in stress, masking, or behavioral effects to marine invertebrates occurring close to a sound source. These effects would generally be short term and brief, and a small number of individuals would be affected relative to overall population sizes. Physiological or behavioral effects resulting from sonar and other sounds are unlikely to impact survival, growth, recruitment, or reproduction of invertebrate populations or subpopulations.

Testing activities using sonar or other transducers would not occur in designated black abalone critical habitat. In addition, sound associated with training activities would not affect essential biological features of critical habitat, which consist of adequate substrate, food availability, and water quality and circulation patterns. Due to the limited range of sound detection and infrequent use of sonar in relatively shallow waters where abalone species occur, physiological or behavioral reactions due to sonar exposure are unlikely. Pursuant to the ESA, the use of sonar and other transducers during testing activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.1.2.3 Impacts from Sonar and Other Transducers Under the No Action Alternative

Impacts from Sonar and Other Transducers Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various acoustic stressors (e.g., sonar and other transducers) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.1.3 Impacts from Air Guns

Air guns produce shock waves that are somewhat similar to those produced by explosives (see Section 3.4.3.2.2, Impacts from Explosives) but of lower intensity and slower rise times. An impulsive sound is generated when pressurized air is released into the surrounding water. Some studies of air gun impacts on marine invertebrates have involved the use of an array of multiple seismic air guns, although arrays are not used during Navy training and testing activities. The volume capacity of air guns used for Navy testing (60 cubic inches at full capacity) is generally within the volume range of single air guns used in seismic exploration (typically 20 to 800 cubic inches). However, seismic air guns are used in arrays with a total volume of several thousands of cubic inches, which is far more than would be associated with any Navy activities. Generated impulses would have short durations, typically a few hundred milliseconds. The root-mean-squared SPL and SEL at a distance of 1 m from the air gun would be approximately 200 to 210 dB re 1 µPa and 185 to 195 dB re 1 μPa^2-s, respectively.

The results of studies of the effects of seismic air guns on marine invertebrates, described in detail in Section 3.4.3.1 (Acoustic Stressors), suggest possible differences between taxonomic groups and life stages. Physical injury has not been reported in relatively crustaceans (crabs, shrimp, and lobsters) exposed to seismic air guns at received levels comparable to the source level of Navy air guns operated at full capacity, but one study reported injury and mortality for zooplankton at exposures below Navy source levels. Evidence of physiological stress was not found in crabs exposed to sound levels up to 187 dB re 1 μPa^2. However, stress response was reported for lobsters located about 3.5 m from the source, where particle motion was likely detectable. While behavioral reaction to air guns has not been documented for crustaceans, squid have exhibited startle and alarm responses at various sound levels. Squid have shown startle response at received levels of 156 to 174 dB re 1 µPa rms (distance from sound source is unclear but presumed to be 30 m based on experimental description), although the reactions were less intense when ramp-up procedures (beginning with lower-intensity sound and progressing to higher levels) were used. In one study, onset of alarm response occurred at 147 dB re 1 μPa^2-s; distance from the source was not provided. Developmental effects to crab eggs and scallop larvae were found at received levels of 210 and 164 dB 1 µPa SPL (about 7 ft. from the source). Conversely, crab zoeae located 62 ft. from an air gun source showed no developmental effects. Air gun use could also result in substrate vibration, which could cause behavioral effects in nearby benthic invertebrates.

3.4.3.1.3.1 Impacts from Air Guns Under Alternative 1

Impacts from Air Guns Under Alternative 1 for Training Activities

There would be no air gun use associated with training activities. Therefore, air guns are not analyzed in this subsection.

Impacts from Air Guns Under Alternative 1 for Testing Activities

Air guns would be used for a limited number of activities in offshore areas of the Hawaii Range Complex and Southern California Range Complex, and at pierside locations at Naval Base San Diego. Sounds produced by air guns are described in Section 3.0.3.3.1.2 (Air Guns).

Compared to offshore areas where air gun use would primarily affect invertebrates in the water column, air gun use at pierside locations would potentially affect a greater number of benthic and sessile invertebrates due to proximity to the bottom and structures (e.g., pilings) that may be colonized by invertebrates. Invertebrates such as sponges, hydroids, worms, bryozoans, bivalves, snails, and numerous types of crustaceans and echinoderms could be exposed to sound. Air gun use in offshore areas has the potential to affect pelagic invertebrates such as jellyfish and squid. Zooplankton could be affected by air gun use at any location. Available information indicates that zooplankton could be injured or killed, but injury to relatively large crustaceans (e.g., lobsters and crabs) would not be expected. Potential injury to squid located very near the source has been suggested but not demonstrated. It is unlikely that air guns would affect egg or larva development due to the brief time that they would be exposed to impulsive sound (a few hundred milliseconds per firing). Activities conducted at pierside locations could potentially result in multiple exposures of sessile species or species with limited mobility to impulsive sound. Air gun use in offshore areas would be unlikely to affect individuals multiple times due to the relative mobility of invertebrates in the water column (passive and active movement) and the mobile nature of the sound source. Some number of invertebrates of various taxa exposed to air gun noise could experience a physiological stress response and would likely show startle reactions or short-term behavioral changes. For example, squid exposed to air gun noise would probably react behaviorally (e.g., inking, jetting, or changing swim speed or location in the water column), as these behaviors were observed in animals exposed to sound levels lower than the source levels of Navy air guns (distance from the source associated with these reactions was not provided). The results of one study suggests that affected individuals may exhibit less intense reactions when exposed to multiple air gun firings (McCauley et al., 2000). In shallow water where air gun firing could cause sediment vibration, nearby benthic invertebrates could react behaviorally (e.g., shell closing or changes in foraging activity). Adult crustaceans may be less affected than some other life stages.

Sound and sediment vibrations caused by air gun events would be brief, although multiple firings would occur per event. In addition, testing activities would be conducted infrequently. Although some individuals would be affected, the number would be small relative to overall population sizes, and activities would be unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

Air guns would not be used in shallow areas known to support ESA-listed abalone species. Abalones generally may be found on artificial structures such as pilings and therefore could conceivably occur at pierside locations at Naval Base San Diego; however, there is no known occurrence of ESA-listed abalone species at these locations. Air guns would not be used within designated black abalone critical habitat and critical habitat has not been designated for white abalone under ESA. Pursuant to the ESA, the use of air guns during testing activities, as described under Alternative 1, would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.1.3.2 Impacts from Air Guns Under Alternative 2

Impacts from Air Guns Under Alternative 2 for Training Activities

There would be no air gun use associated with training activities. Therefore, air guns are not analyzed in this subsection.

Impacts from Air Guns Under Alternative 2 for Testing Activities

The locations, number of events, and potential effects associated with air gun use would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.1.3.1 (Impacts from Air Guns Under Alternative 1) for a discussion of impacts on invertebrates.

Air guns would not be used in shallow areas known to support ESA-listed abalone species. Abalones generally may be found on artificial structures such as pilings and therefore could conceivably occur at pierside locations at Naval Base San Diego; however, there is no known occurrence of ESA-listed abalone species at these locations. Air guns would not be used within designated black abalone critical habitat and critical habitat has not been designated for white abalone under ESA. Pursuant to the ESA, the use of air guns during testing activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.1.3.3 Impacts from Air Guns Under the No Action Alternative

Impacts from Air Guns Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed testing activities in the HSTT Study Area. Various acoustic stressors (e.g., air guns) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.1.4 Impacts from Pile Driving

Pile driving and removal involves both impact and vibratory methods. Impact pile driving produces repetitive, impulsive, broadband sound with most of the energy in lower frequencies where invertebrate hearing sensitivity is greater. Vibratory pile removal produces nearly continuous sound at a lower source level. See Section 3.0.3.3.1.3 (Pile Driving) for a discussion of sounds produced during impact pile driving and vibratory pile removal.

Impacts on invertebrates resulting from pile driving and removal are considered in the context of impulsive sound and substrate vibration. Impact pile driving produces a pressure wave that is transmitted to the water column and the sediment (Reinhall & Dahl, 2011). The pressure wave may cause vibration within the sediment. Most acoustic energy would be concentrated below 1,000 Hz, which is within the general sound sensing range of invertebrates. Available information indicates that invertebrates may respond to particle motion and substrate vibration produced by pile driving or removal. As discussed in Section 3.4.3.1 (Acoustic Stressors), recent investigations have found effects to crustacean and mollusc species resulting from pile driving noise playback and substrate vibration (Roberts et al., 2015; Roberts et al., 2016a; Solan et al., 2016; Spiga, 2016). Responses include changes in chorusing (snapping shrimp), shell closing (clams and mussels), and changes in activity level (clams, lobsters, and hermit crabs). However, no statistically detectable changes were observed in brittlestars, suggesting that impacts may vary among taxa or species. While one study was conducted in a sheltered coastal area (Spiga, 2016), the others used small experimental tanks with maximum dimension of about 20 inches (in.). Therefore, many of the effects were observed very close to the sound sources. Navy scientists are in the early stages of observing the response of marine life to pile driving in their unconfined environment using an adaptive resolution imaging sonar that allows observations in low visibility estuarine waters. Samples acquired to date include the response (or lack thereof) of various fish and crabs to Navy pile driving in the Mid-Atlantic region (Chappell, 2018).

3.4.3.1.4.1 Impacts from Pile Driving Under Alternative 1

Impacts from Pile Driving Under Alternative 1 for Training Activities

Under Alternative 1, pile driving and removal associated with elevated causeway system placement would occur up to two times per year at Silver Strand Training Complex or Camp Pendleton, both in the

Southern California Range Complex. Marine invertebrates in the area around a pile driving and vibratory removal site would be exposed to multiple impulsive sounds and other disturbance intermittently over an estimated 20 days during installation and 10 days during removal. Invertebrates could be exposed to impact noise for a total of 90 minutes per 24-hour period during installation, and could be exposed to noise and substrate vibration for a total of 72 minutes per 24-hour period during pile removal. It may be theorized that repeated exposures to impulsive sound could damage the statocyst of individuals of some taxa (e.g., crustaceans and cephalopods); however, experimental data on such effects are not available. Exposure to impulsive sound and substrate vibration would likely cause behavioral reactions in invertebrates located in the water column or on the bottom for some distance from the activities. Reactions such as shell closure or changes in activity could affect feeding, and auditory masking could affect other behaviors such as communication and predator avoidance. Repetitive impulses and substrate vibration may also cause short-term avoidance of the affected area by mobile invertebrates. Available experimental results do not provide estimates of the distance to which such reactions could occur. Although some number of individuals would experience physiological and behavioral effects, the activities would occur intermittently (two events occurring intermittently over approximately 30 days per year) in very limited areas and would be of short duration (maximum of 90 minutes per 24-hour period). Therefore, the number of invertebrates affected would be small compared to overall population numbers. Pile driving and removal activities would be unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

Pile driving activities would not be conducted in areas that could support black abalone or white abalone occurrence, and would not occur in black abalone critical habitat. Critical habitat for white abalone is not designated under the ESA. Pursuant to the ESA, pile driving and removal during training activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Pile Driving Under Alternative 1 for Testing Activities

There would be no pile driving or removal associated with testing activities. Therefore, pile driving is not analyzed in this subsection.

3.4.3.1.4.2 Impacts from Pile Driving Under Alternative 2

Impacts from Pile Driving Under Alternative 2 for Training Activities

The locations, number of events, and potential effects associated with pile driving and removal would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.4.5.1 (Impacts from Pile Driving Under Alternative 1) for a discussion of impacts on invertebrates.

Pile driving activities would not be conducted in areas that could support black abalone or white abalone occurrence, and would not occur in black abalone critical habitat. Critical habitat for white abalone is not designated under the ESA. Pursuant to the ESA, pile driving and removal during training activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Pile Driving Under Alternative 2 for Testing Activities

There would be no pile driving or removal associated with testing activities. Therefore, pile driving is not analyzed in this subsection.

3.4.3.1.4.3 Impacts from Pile Driving Under the No Action Alternative

Impacts from Pile Driving Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training activities in the HSTT Study Area. Various acoustic stressors (e.g., pile driving) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.1.5 Impacts from Vessel Noise

As described in Section 3.0.3.3.1.4 (Vessel Noise), naval vessels (including ships and small craft) produce low-frequency, broadband underwater sound that ranges over several sound levels and frequencies. Some invertebrate species would likely be able to detect the low-frequency component of vessel noise. Several studies, described in detail in Section 3.4.3.1 (Acoustic Stressors), have found physiological and behavioral responses in some invertebrate species in response to playback of vessel noise, although one study found no reaction by krill to an approaching vessel. Physiological effects included biochemical changes indicative of stress in crustacean species, decreased growth and reproduction in shrimp, and changes in sea hare embryo development. It is also possible that vessel noise may contribute to masking of relevant environmental sounds, such as predator detection or reef sounds. Low-frequency reef sounds are used as a settlement cue by the larvae of some invertebrate species. Behavioral effects resulting from boat noise playback have been observed in various crustacean, cephalopod, and bivalve species and include shell closing and changes in feeding, coloration, swimming, and other movements. Exposure to other types of non-impulsive noise (and therefore potentially relevant to vessel noise effects), including continuous sweeps and underwater turbine noise playback, has resulted in statocyst damage (squid and octopus), physiological stress, effects to larval development, and behavioral reactions. Noise exposure in several of the studies using boat and other continuous noise sources occurred over a duration of 3.5 to 30 minutes to captive individuals unable to escape the stimulus. In other studies, noise playback ranged from hours to days (and up to 3 months in one investigation) of continuous or intermittent exposure. Given the duration of exposure, direct applicability of the results to Navy training and testing activities is uncertain for mobile species. However, it is possible that invertebrates in the Study Area that are exposed to vessel noise could exhibit similar reactions.

While commercial vessel traffic and associated noise is relatively steady over time, Navy traffic is episodic in the ocean. Activities involving vessel movements occur intermittently and are variable in duration, ranging from a few hours to a few weeks. Vessels engaged in training and testing may consist of a single vessel involved in unit-level activity for a few hours or multiple vessels involved in a major training exercise that could last a few days within a given area. In the West Coast Exclusive Economic Zone, Navy ships are estimated to contribute roughly 10 percent of the total large vessel broadband energy noise (Mintz, 2012).

3.4.3.1.5.1 Impacts from Vessel Noise Under Alternative 1

Impacts from Vessel Noise Under Alternative 1 for Training Activities

Under Alternative 1, naval vessels would be used during many of the proposed activities, and naval vessel noise associated with vessel transit during training could occur throughout the Study Area. However, Navy traffic would be heaviest in the eastern portion of the Southern California Range Complex and in the area off the southern coast of Oahu. Noise exposure would be particularly concentrated near naval port facilities.

Marine invertebrates capable of sensing sound may alter their behavior or experience masking of other sounds if exposed to vessel noise. Because the distance over which most marine invertebrates are expected to detect sounds is limited, and because most vessel noise is transient or intermittent (or both), most behavioral reactions and masking effects from Navy activities would likely be short-term, ceasing soon after Navy vessels leave an area. An exception would be areas in and around port navigation channels and inshore waters that receive a high volume of ship or small craft traffic, where sound disturbance would be more frequent. The relatively high frequency and intensity of vessel traffic in many inshore training areas may have given organisms an opportunity to adapt behaviorally to a noisier environment. For example, recent survey work by the Virginia Institute of Marine Science suggests that large populations of oysters inhabit Navy piers in the Chesapeake Bay that have persisted despite a history of chronic vessel noise (Horton, 2016). Without prolonged exposure to nearby sounds, measurable impacts are not expected. In general, intermittent vessel noise produced during training activities may briefly impact some individuals, but exposures are not expected to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations. Concentrated vessel operation in areas such as port navigation channels could result in repeated noise exposure and chronic physiological or behavioral effects to individuals of local invertebrate subpopulations, particularly sessile species, located near the sound source. However, vessel noise would not be expected to adversely affect the viability of common or widely distributed invertebrate species in navigation channels or near naval port facilities.

The potential effects of vessel noise on ESA-listed abalone species have not been studied. Abalone sound sensing ability, like other marine invertebrates, is likely limited to nearby particle motion. Therefore, abalones would likely only detect vessel noise very near the source. Vessel noise would not affect essential biological features of black abalone critical habitat, and critical habitat has not been designated for white abalone under the ESA. Pursuant to the ESA, vessel noise during training activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Vessel Noise Under Alternative 1 for Testing Activities

Under Alternative 1, naval vessels would be used during many of the proposed activities, and naval vessel noise associated with testing could occur throughout the Study Area while in transit. However, Navy traffic would be heaviest in the eastern portion of the Southern California Range Complex and in the area off the southern coast of Oahu. Noise exposure would be particularly concentrated near naval port facilities.

Any marine invertebrate capable of sensing sound may alter its behavior or experience masking of other sounds if exposed to vessel noise. Because the distance over which most marine invertebrates are expected to detect sounds is limited and because most vessel noise is transient or intermittent (or both), most behavioral reactions and masking effects from Navy activities would likely be short term, ceasing soon after Navy vessels leave an area. An exception would be areas in and around port navigation channels and inshore waters that receive a high volume of ship or small craft traffic, where sound disturbance would be more frequent. The relatively high frequency and intensity of vessel traffic in many inshore areas may have given organisms an opportunity to adapt behaviorally to a noisier environment. For example, recent survey work by the Virginia Institute of Marine Science suggests that large populations of oysters inhabit Navy piers in the Chesapeake Bay that have persisted despite a history of chronic vessel noise (Horton, 2016). Without prolonged exposure to nearby sounds, measurable impacts are not expected. In general, intermittent vessel noise produced during testing activities may briefly impact some individuals, but exposures are not expected to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations. Concentrated vessel operation in areas such as port navigation channels could result in repeated noise exposure and chronic physiological or behavioral effects to individuals of local invertebrate subpopulations, particularly sessile species, located near the sound source. However, vessel noise would not be expected to adversely affect the viability of common or widely distributed invertebrate species in navigation channels or near naval port facilities.

The potential effects of vessel noise on ESA-listed abalone species have not been studied. Abalone sound sensing ability, like other marine invertebrates, is likely limited to nearby particle motion. Abalones would therefore likely only detect vessel noise very near the source. Vessel noise would not affect essential biological features of black abalone critical habitat, and critical habitat has not been designated for white abalone under the ESA. Pursuant to the ESA, vessel noise during testing activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.1.5.2 Impacts from Vessel Noise Under Alternative 2

Impacts from Vessel Noise Under Alternative 2 for Training Activities

Under Alternative 2, potential impacts on invertebrates resulting from vessel noise associated with training activities would be similar to those discussed for activities under Alternative 1. Vessel use in the Study Area would increase by a very small amount (less than 1 percent) due to differences in the number of events such as Composite Training Unit Exercises. However, the increase would not result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.1.5.1 (Impacts from Vessel Noise Under Alternative 1) for a discussion of potential impacts.

As discussed in Section 3.4.3.1.5.1 (Impacts from Vessel Noise under Alternative 1), pursuant to the ESA, vessel noise during training activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Vessel Noise Under Alternative 2 for Testing Activities

Under Alternative 2, potential impacts on invertebrates resulting from vessel noise associated with testing activities would be similar to those discussed for activities under Alternative 1. Vessel use in the Study Area would increase by a very small amount (less than 1 percent). However, the increase would not result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.1.5.1 (Impacts from Vessel Noise Under Alternative 1) for a discussion of potential impacts.

As discussed in Section 3.4.3.1.5.1 (Impacts from Vessel Noise Under Alternative 1), pursuant to the ESA, vessel noise during testing activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.1.5.3 Impacts from Vessel Noise Under the No Action Alternative

Impacts from Vessel Noise Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various acoustic stressors (e.g., vessel noise) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.1.6 Impacts from Aircraft Noise

Aircraft noise is not applicable to invertebrates due to the very low transmission of sound pressure across the air/water interface and will not be analyzed further in this section.

3.4.3.1.7 Impacts from Weapons Noise

As discussed in Section 3.0.3.3.1.6 (Weapon Noise), noise associated with weapons firing and the impact of non-explosive munitions could occur during training or testing events. In-water noise would result from naval gunfire (muzzle blast), bow shock waves from supersonic projectiles, missile and target launch, and vibration from a blast propagating through a ship's hull. In addition, larger non-explosive munitions could produce low-frequency impulses when striking the water, depending on the size, weight, and speed of the object at impact. Small- and medium-caliber munitions would not produce substantial impact noise.

Underwater sound produced by weapons firing, launch, and impact of non-explosive practice munitions would be greatest near the surface and would attenuate with depth. However, the potential for in-air weapons noise to impact invertebrates would be small. Much of the energy produced by muzzle blasts and flying projectiles is reflected off the water surface. As discussed in Section 3.0.3.3.1.6 (Weapon Noise), sound generally enters the water only in a cone beneath the blast or projectile trajectory (within 13 to 14 degrees of vertical for muzzle blast noise, and 65 degrees behind the projectile in the direction of fire for projectile shock waves). An SEL of 180 to 185 dB re 1 μPa^2-s was measured at water depth of 5 ft. directly below the muzzle blast of the largest gun analyzed, at the firing position closest to the water. Different weapons and angles of fire would produce less sound in the water. Bow waves from supersonic projectiles produce a brief "crack" noise at the surface, but transmission of sound into the water is minimal. Launch noise fades rapidly as the missile or target moves downrange and the booster burns out. Hull vibration from large-caliber gunfire produces only a small level of underwater noise. For example, analysis of 5-in. gun firing found that energy transmitted into the water by hull vibration is only 6 percent of that produced by the muzzle blast. Compared to weapons firing, launches, and hull vibration, impulsive sound resulting from non-explosive practice munition strikes on the water surface could affect a somewhat larger area, though far less than an explosive blast. Underwater sound would generally be associated only with relatively large munitions impacting at high speed.

Based on the discussion above, invertebrates would likely only be affected by noise produced by muzzle blasts and impact of large non-explosive practice munitions. Impacts would likely be limited to pelagic invertebrates, such as squid, jellyfish, and zooplankton, located near the surface. Injury and physiological stress has not been found in limited studies of invertebrates exposed to impulsive sound levels comparable to those produced beneath the muzzle blast of a 5-in. gun. Behavioral reactions have not been found in crustaceans, but have been observed for squid. While squid could display short-term startle response, behavioral reactions in response to sound is not known for jellyfish or zooplankton. Zooplankton may include gametes, eggs, and larval forms of various invertebrate species, including corals. Although prolonged exposure to repeated playback of nearby impulsive sound (air guns) has resulted in developmental effects to larvae and eggs of some invertebrate species, brief exposure to a single or limited number of muzzle blasts or munition impacts would be unlikely to affect development. Other factors would limit the number and types of invertebrates potentially affected. Most squid are active near the surface at night, when weapons firing and launch occur infrequently. Weapons firing and launch typically occurs greater than 12 nautical miles [NM] from shore, which because of the water depths would substantially limit the sound level reaching the bottom. Therefore, impacts on benthic invertebrates (e.g., bivalve molluscs, worms, and crabs) are unlikely.

3.4.3.1.7.1 Impacts from Weapons Noise Under Alternative 1

Impacts from Weapons Noise Under Alternative 1 for Training Activities

Under Alternative 1, invertebrates would be exposed to noise primarily from weapons firing and impact of non-explosive practice munitions during training activities. Noise associated with large caliber weapons and the impact of non-explosive practice munitions would generally occur at locations greater than 12 NM from shore, with the exception of areas near San Clemente Island in the Southern California Range Complex and near Kaula Island and the Pacific Missile Range Facility in the Hawaii Range Complex. Small caliber weapons firing could occur throughout the Study Area. The number of training events involving weapons firing, launch, and non-explosive practice munitions and their proposed locations are presented in Table 2.6-1 of Chapter 2 (Description of Proposed Action and Alternatives).

Noise produced by these activities would consist of a single or several impulses over a short period. Impulses resulting from muzzle blasts and non-explosive practice munitions impact would likely affect only individuals near the surface, and are not likely to result in injury. Some invertebrates may exhibit startle reactions (e.g., abrupt changes in swim speed or direction). For example, based on observed reactions to other impulsive sounds (air guns), squid located near the surface in the vicinity of a firing event could show startle reactions such as inking or jetting. Impact of non-explosive practice munitions could affect a comparatively larger volume of water and associated invertebrates. The number of organisms affected would depend on the area exposed and the invertebrate density. Squid and zooplankton are typically more abundant near the surface at night, when weapon firing occurs infrequently. In addition, most weapons firing would take place in offshore waters, decreasing the potential for impacts on benthic invertebrates and abalone eggs or zygotes.

Impacts would be of brief duration and limited to a relatively small volume of water near the surface. It is expected that only a small number of pelagic invertebrates (e.g., squid, jellyfish, and zooplankton) would be exposed to weapons firing and impact noise. Squid and zooplankton would be less abundant during the day, when weapons firing typically occurs, and jellyfish are not known to react to sound. The activities would be unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

Most weapons firing and launch would occur in relatively deep offshore areas where in-air noise and hull vibration would not affect ESA-listed abalone species. Large-caliber weapons, small-caliber weapons, and non-explosive practice munitions could produce in-water noise near San Clemente Island, where ESA-listed abalone species occur. However, impacts to benthic invertebrates such as abalones would be unlikely. Activities would not occur in designated black abalone critical habitat. Critical habitat has not been designated for white abalone under the ESA. Pursuant to the ESA, weapons noise during training activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Weapons Noise Under Alternative 1 for Testing Activities

Under Alternative 1, invertebrates would be exposed to noise primarily from weapons firing and impact of non-explosive practice munitions during testing activities. Noise associated with large caliber weapons and the impact of non-explosive practice munitions would generally occur at locations greater than 12 NM from shore, with the exception of areas near San Clemente Island in the Southern California Range Complex and near Kaula Island and the Pacific Missile Range Facility in the Hawaii Range Complex. Small caliber weapons firing could occur throughout the Study Area.

Noise produced by these activities would consist of a single or several impulses over a short period. Impulses resulting from muzzle blasts and non-explosive practice munitions impact would likely affect only individuals near the surface, and are not likely to result in injury. Some invertebrates may exhibit startle reactions (e.g., abrupt changes in swim speed or direction). For example, based on observed reactions to other impulsive sounds (air guns), squid located near the surface in the vicinity of a firing event could show startle reactions such as inking or jetting. Impact of non-explosive practice munitions could affect a comparatively larger volume of water and associated number of invertebrates. The number of organisms affected would depend on the area exposed and the invertebrate density. Squid and zooplankton are typically more abundant near the surface at night, when weapon firing occurs infrequently. In addition, most weapons firing would take place in offshore waters, decreasing the potential for impacts on benthic invertebrates and abalone eggs or zygotes.

Impacts would be of brief duration and would be limited to a relatively small volume of water near the surface. It is expected that only a small number of pelagic invertebrates (e.g., squid, jellyfish, and zooplankton) would be exposed to weapons firing and impact noise. Squid and zooplankton would be less abundant during the day, when weapons firing typically occurs, and jellyfish are not known to react to sound. The activities would be unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

Most weapons firing and launch would occur in relatively deep offshore areas where in-air noise and hull vibration would not affect ESA-listed abalone species. Large-caliber weapons, small-caliber weapons, and non-explosive practice munitions could produce in-water noise near San Clemente Island, where ESA-listed abalone species occur. However, impacts to benthic invertebrates such as abalones would be unlikely. Activities would not occur in designated black abalone critical habitat. Pursuant to the ESA, weapons noise during testing activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.1.7.2 Impacts from Weapons Noise Under Alternative 2

Impacts from Weapons Noise Under Alternative 2 for Training Activities

The locations, number of events, and potential effects associated with weapons firing, launch, and non-explosive practice munitions impact noise for training activities would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.1.7.1 (Impacts from Weapons Noise Under Alternative 1) for a discussion of impacts on invertebrates.

Most weapons firing and launch would occur in relatively deep offshore areas where in-air noise and hull vibration would not affect ESA-listed abalone species. Large-caliber weapons, small-caliber weapons, and non-explosive practice munitions could produce in-water noise near San Clemente Island, where ESA-listed abalone species occur. However, impacts to benthic invertebrates such as abalones would be unlikely. Activities would not occur in designated black abalone critical habitat. Critical habitat has not been designated for white abalone under the ESA. Pursuant to the ESA, weapons noise during training activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Weapons Noise Under Alternative 2 for Testing Activities

Under Alternative 2, the location of testing activities would be the same as those described for Alternative 1, and potential impacts on invertebrates would be similar (refer to Section 3.4.3.1.7.1, Impacts from Weapons Noise Under Alternative 1). The only difference between Alternatives 1 and 2 is that the number of munitions used would potentially be greater under Alternative 2. While the types of expected impacts on any individual invertebrate or group of invertebrates capable of detecting sounds produced during testing activities would remain the same, more animals could be affected because the number of munitions potentially used during testing activities under Alternative 2 would be greater. It is expected that only a small number of pelagic invertebrates (e.g., squid, jellyfish, and zooplankton) would be exposed. Squid and zooplankton would be less abundant near the surface during the day, when weapons firing typically occurs, and jellyfish are not known to react to sound. The activities would be unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

Activities would not impact ESA-listed black abalone or white abalone, and would not occur in designated black abalone critical habitat. Pursuant to the ESA, weapons noise during testing activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.1.7.3 Impacts from Weapons Noise Under the No Action Alternative

<u>Impacts from Weapons Noise Under the No Action Alternative for Training and Testing Activities</u>

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various acoustic stressors (e.g., weapons firing, launch, and non-explosive practice munitions impact noise) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.1.8 Summary of Potential Acoustic Impacts

Invertebrates would be exposed to potential acoustic stressors resulting from sonar and other transducers; pile driving; air guns; weapons firing, launch, and non-explosive practice munitions impact noise; and vessel noise. Based on currently available information, invertebrates would only sense water particle motion near a sound source and at low frequencies, which limits the distance from the source in which individual invertebrates would potentially be exposed to acoustic impacts. The potential for injury would be limited to invertebrates occurring very close to an impulsive sound such as an air gun. Impacts would primarily consist of physiological stress or behavioral reactions. Most sound exposures would occur in offshore areas and near the surface, where pelagic species such as squid, jellyfish, and zooplankton would be affected. Squid and some zooplankton species occur infrequently at the surface during the day, when most Navy activities would take place. Overall, there would be comparatively fewer impacts on benthic species. Exceptions would include pierside sonar and air gun use, and concentration of vessel operation in certain areas, where sessile or sedentary individuals could be repeatedly exposed to acoustic stressors. Most sound exposures would be brief and transient and would affect small numbers of individuals.

3.4.3.2 Explosive Stressors

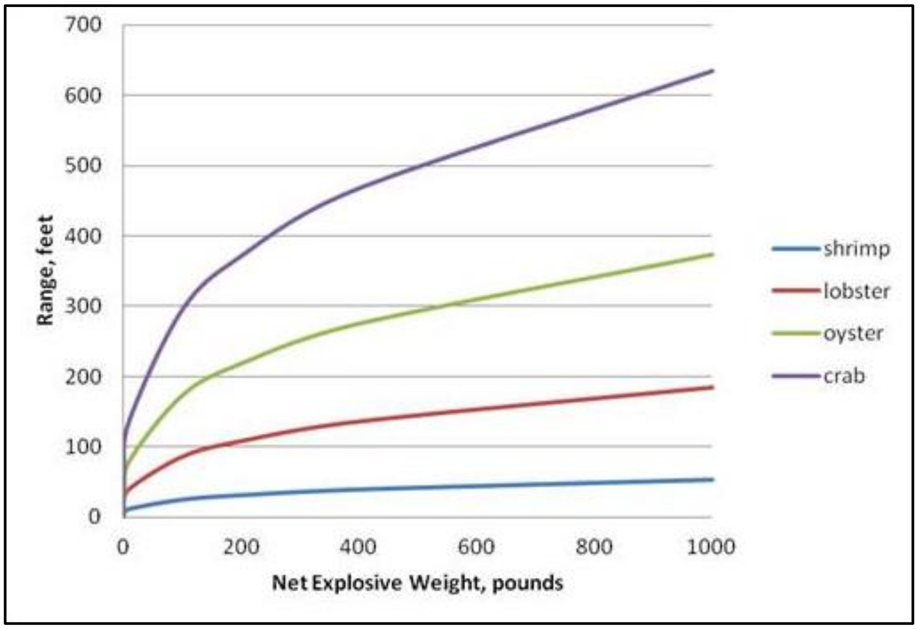
3.4.3.2.1 Background

Aspects of explosive stressors that are applicable to marine organisms in general are presented in Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities). Explosions produce pressure waves with the potential to cause injury or physical disturbance due to rapid pressure changes, as well as loud, impulsive, broadband sounds. Impulsive sounds are characterized by rapid pressure rise times and high peak pressures (Appendix D, Acoustic and Explosive

Concepts). Potential impacts on invertebrates resulting from the pressure wave and impulsive sound resulting from a detonation are discussed in this section. When explosive munitions detonate, fragments of the weapon are thrown at high velocity from the detonation point, which can injure or kill invertebrates if they are struck. However, the friction of the water quickly slows these fragments to the point where they no longer pose a threat. Given the small range of effects due to fragments, the potential for impacts on invertebrates at the population or subpopulation level would be negligible. Therefore, the potential for fragmentation to impact invertebrates is not discussed further in this analysis.

Explosions may impact invertebrates at the water surface, in the water column, or on the bottom. The potential for impacts is influenced by typical detonation scenarios and invertebrate distribution. The majority of explosions would occur in the air or at the surface, with relatively few at the bottom (Appendix A, Navy Activity Descriptions), which would decrease the potential for impacts on benthic invertebrate species. Surface explosions typically occur during the day at offshore locations more than 12 NM from shore. There is a general pattern of lower invertebrate abundance in offshore portions of the Study Area compared to relatively productive estuarine and nearshore waters. Therefore, the typical offshore location of detonations would result in fewer invertebrates potentially exposed to detonation effects. In addition, invertebrate abundances in offshore surface waters tend to be lower during the day, when surface explosions typically occur, than at night.

In general, an explosion may result in direct trauma and mortality due to the associated rapid pressure changes. For example, gas-containing organs such as the swim bladder in many fish species and the lungs of marine mammals are subject to rapid contraction and overextension (potentially causing rupture) when exposed to explosive shock waves. Most marine invertebrates lack air cavities and are therefore comparatively less vulnerable to damaging effects of pressure waves. A report summarizing the results of all known historical experiments (from 1907 to the 1980s) involving invertebrates and detonations concluded that marine invertebrates are generally insensitive to pressure-related damage from underwater explosions (Keevin & Hempen, 1997). Limited studies of crustaceans have examined mortality rates at various distances from detonations in shallow water (Aplin, 1947; Chesapeake Biological Laboratory, 1948; Gaspin et al., 1976). Similar studies of molluscs have shown them to be more resistant than crustaceans to explosive impacts (Chesapeake Biological Laboratory, 1948; Gaspin et al., 1976). Other invertebrates, such as sea anemones, polychaete worms, isopods, and amphipods, were observed to be undamaged in areas near detonations (Gaspin et al., 1976). Data from these experiments were used to develop curves that estimate the distance from an explosion beyond which at least 90 percent of certain adult benthic marine invertebrates would survive, depending on the weight of the explosive (Young, 1991) (Figure 3.4-1). For example, 90 percent of crabs would survive a 200-lb. explosion if they are greater than about 350 ft. from the source, and shrimp, lobster, and oysters are less sensitive (i.e., greater survivability) to underwater explosions than crabs. Similar information on the effects of explosions to planktonic invertebrates and invertebrate larvae is not available.



Source: Young (1991)

Figure 3.4-1: Prediction of Distance to 90 Percent Survivability of Marine Invertebrates Exposed to an Underwater Explosion

Charges detonated in shallow water or near the bottom, including explosive munitions disposal charges and some explosions associated with mine warfare, could kill and injure marine invertebrates on or near the bottom, depending on the species and the distance from the explosion. Taxonomic groups typically associated with the bottom, such as sponges, marine worms, crustaceans, echinoderms, corals, and molluscs, could be affected. Net explosive weight (NEW) for activities involving detonations on or near the bottom is relatively low. Most detonations occurring on or near the bottom would have a NEW of 60 lb. or less, although some explosives would be up to 1,000 lb. NEW. Based on the estimates shown on Figure 3.4-1, most benthic marine invertebrates beyond approximately 275 ft. from a 60-lb. blast would survive. The potential mortality zone for some taxa (e.g., shrimp, lobsters, worms, amphipods) would be substantially smaller. A blast near the bottom could disturb sessile invertebrates such as mussels and hard substrate suitable for their colonization. A blast in the vicinity of hard corals could cause direct impact on coral polyps or early life-stages of pre-settlement corals, or fragmentation and siltation of the corals. For example, in one study, moderate to substantial recovery from a single small blast directly on a reef was observed within 5 years, but reef areas damaged by multiple blasts showed no evidence of recovery during the 6-year observation period (Fox & Caldwell, 2006). In another study, modeling results indicated that deep-water corals off Alaska damaged by trawling activities could require over 30 years to recover 80 percent of the original biomass (Rooper et al., 2011). The extent of trawling damage is potentially greater than that associated with detonations due to the small footprints of detonations compared to the larger surface area typically affected by trawling, as well as the avoidance of known shallow-water coral reefs and live hard bottom habitat during activities involving detonations. While the effects of trawling activities and underwater detonations are not directly comparable, the trawling model results illustrate the extended recovery time that may be required for deep-water coral regrowth following physical disturbance.

Impacts on benthic invertebrates in deeper water would be infrequent because most offshore detonations occur in the air or at the surface. Benthic invertebrates in the abyssal zone (generally considered to be deeper than about 6,000 ft.) seaward of the coastal large marine ecosystems are sparsely distributed and tend to be concentrated around hydrothermal vents and cold seeps. These topographic features are typically associated with steep or high-relief areas of the continental shelf break (e.g., canyons, outcrops) or open ocean (e.g., seamounts).

Underwater surveys of a Navy bombing range in the Pacific Ocean (Farallon De Medinilla) were conducted annually from 1999 to 2012 (Smith & Marx, 2016). Although Farallon De Medinilla is a land range, bombs and other munitions occasionally strike the water. A limited number of observations of explosion-related effects were reported, and the results are summarized here to provide general information on the types of impacts that may occur. However, the effects are not presumed to be broadly applicable to Navy training and testing activities. During the 2010 survey, it was determined that a blast of unknown size (and therefore of unknown applicability to proposed training and testing activities) along the waterline of a cliff ledge caused mortality to small oysters near the impact point. Corals occurring within 3 m of the affected substrate were apparently healthy. A blast crater on the bottom that was 5 m in diameter and 50 cm deep, presumably resulting from a surface detonation, was observed during one survey in water depth of 12 m. Although it may be presumed that corals or other invertebrates located within the crater footprint would have been damaged or displaced, evidence of such impacts was not detected. The blast occurred in an area of sparse coral coverage and it is therefore unknown whether coral was present in the crater area prior to the blast.

The applicability of the mortality distance estimates shown on Figure 3.4-1 to invertebrates located in the water column is unknown. However, detonations that occur near the surface release a portion of the explosive energy into the air rather than the water, reducing impacts on invertebrates in the water column. In addition to effects caused by a shock wave, organisms in an area of cavitation that forms near the surface above a large underwater detonation could be killed or injured. Cavitation is where the reflected shock wave creates a region of negative pressure followed by a collapse, or water hammer (see Appendix D, Acoustic and Explosive Concepts). The number of organisms affected by explosions at the surface or in the water column would depend on the size of the explosive, the distance of organisms from the explosion, and the specific geographic location within the Study Area. As discussed previously, many invertebrates that occur near the surface at night (e.g., squid and zooplankton) typically move down in the water column during the day, making them less vulnerable to explosions when most Navy activities involving detonations occur.

Marine invertebrates beyond the range of mortality or injurious effects may detect the impulsive sound produced by an explosion. At some distance, impulses lose their high pressure peak and take on characteristics of non-impulsive acoustic waves. Invertebrates that detect impulsive or non-impulsive sounds may experience stress or exhibit behavioral reactions in response to the sound (see Section 3.4.3.1.1, Background). Repetitive impulses during multiple explosions, such as during a surface firing exercise, may be more likely to cause avoidance reactions. However, the distance to which invertebrates are likely to detect sounds is limited due to their sensitivity to water particle motion caused by nearby low-frequency sources. Sounds produced in water during training and testing activities, including activities that involve multiple impulses, occur over a limited duration. Any auditory masking, in which the sound of an impulse could prevent detection of other biologically relevant sounds, would be very brief.

3.4.3.2.2 Impacts from Explosives

3.4.3.2.2.1 Impacts from Explosives Under Alternative 1

Impacts from Explosives Under Alternative 1 for Training Activities

Under Alternative 1, marine invertebrates would be exposed to surface and underwater explosions and associated underwater impulsive sounds from high-explosive munitions (including bombs, missiles, torpedoes, and projectiles), mines, and demolition charges. Explosives would be used throughout the Study Area. A discussion of explosives, including explosive source classes, is provided in Section 3.0.3.3.2 (Explosive Stressors). The largest source class proposed for training under Alternative 1 is E12 (650 to 1,000 lb. NEW), used during bombing exercises (air-to-surface) and sinking exercises.

In general, explosive events would consist of a single explosion or a few smaller explosions over a short period, and would occur infrequently over the course of a year. With the exception of mine warfare, demolition, and a relatively small number of other training events that occur in shallow water close to shore (typically in the same locations that are regularly disturbed), most detonations would occur in water depths greater than 200 ft. (but still at the surface) and greater than 3 to 9 NM from shore. As water depth increases away from shore, benthic invertebrates would be less likely to be impacted by detonations at or near the surface because the impact of the underwater impulsive sounds would be dampened. Pelagic invertebrates, such as squid and zooplankton, are typically less abundant near the surface during the day, when explosions typically occur. In addition, detonations near the surface would release a portion of their explosive energy into the air, reducing the potential for impacts on pelagic invertebrates.

Mine warfare activities are typical examples of activities involving detonations on or near the bottom in nearshore waters. Invertebrates in these areas are adapted to frequent disturbance from storms and associated sediment redistribution. Studies of the effects of large-scale sediment disturbance, such as dredging and sediment borrow projects, have found recovery of benthic communities over a period of weeks to years (Posey & Alphin, 2002; U.S. Army Corps of Engineers, 2012). Recovery time is variable and may be influenced by multiple factors, but is generally faster in areas dominated by sand and moderate to strong water movement. The area of bottom habitat disturbed by explosions would be less than that associated with dredging or other large projects, and would occur mostly in soft bottom areas that are regularly disturbed by natural processes such as water currents and waves. It is therefore expected that areas affected by detonations would rapidly be recolonized (potentially within weeks) by recruitment from the surrounding invertebrate community. Craters resulting from detonations in the soft bottom would be filled and smoothed by waves and long-shore currents over time, resulting in no permanent change to bottom profiles that could affect invertebrate species assemblages. The time required to fill craters would depend on the size and depth, with deeper craters likely requiring more time to fill (U.S. Army Corps of Engineers, 2001). The amount of bottom habitat impacted by explosions would be a very small percentage of the habitat available in the Study Area. The total area of bottom habitat potentially disturbed by explosions is estimated at about 16 acres annually for training activities.

Many corals and hard bottom invertebrates are sessile, fragile, and particularly vulnerable to shock wave impacts. Many of these organisms are slow-growing and could require decades to recover (Precht et al., 2001). However, most explosions would occur at or near the water surface and offshore, reducing the likelihood of bottom impacts on shallow-water corals.

In summary, explosives produce pressure waves that can harm invertebrates in the vicinity of where they typically occur: mostly offshore surface waters where only zooplankton, squid, and jellyfish are less abundant during the day when training activities typically occur. Exceptions occur where explosives are used on the bottom within nearshore or inshore waters on or near sensitive hard bottom communities that are currently not mapped or otherwise protected; shallow-water coral reefs are protected from such explosions whereas other live hard bottom communities are protected to the extent they are included in current mitigation measures. Soft bottom communities are resilient to occasional disturbances. Accordingly, the overall impacts of explosions on widespread invertebrate populations would likely be undetectable. Although individuals of widespread marine invertebrate species would likely be injured or killed during an explosion, the number of such invertebrates affected would be small relative to overall population sizes, and activities would be unlikely to impact survival, growth, recruitment, or reproduction of populations or subpopulations. Species with limited distribution, such as stony corals and abalones, would be of greater concern.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from explosives on seafloor resources in mitigation areas throughout the Study Area. For example, the Navy will not conduct explosive mine countermeasure and neutralization activities within a specified distance of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks. The mitigation will consequently also help avoid potential impacts on invertebrates that inhabit these areas, including several areas inhabited by white abalone and black abalone. In addition, procedural mitigations include the requirement to avoid jellyfish aggregations during sinking exercises and the use of explosive torpedoes.

Black abalone are found primarily within the intertidal zone where explosions do not occur, but also occur in the subtidal zone to a depth of about 20 ft. White abalone occur at greater depth. Both species could potentially be exposed to underwater detonations associated with training exercises, although detonations are not expected to occur on the hard substrate or within the depth range associated with black abalone and white abalone. Because the number of underwater detonations is very small, the population density of black abalone and white abalone is very low, and detonations would not typically occur in areas likely to support black abalone and white abalone, the probability of these species being exposed to detonation effects is low. Navy activities would not overlap with designated black abalone critical habitat, and critical habitat has not been designated for white abalone under the ESA. Pursuant to the ESA, the use of explosives during training activities as described under Alternative 1 would have no effect on designated black abalone critical habitat because activities would not occur within designated critical habitat, but may affect ESA-listed abalone species. The Navy has consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from Explosives Under Alternative 1 for Testing Activities

Under Alternative 1, marine invertebrates could be exposed to surface and underwater explosions from high-explosive munitions (including bombs, missiles, torpedoes, and projectiles), mines, demolition charges, explosive sonobuoys, and ship shock trial charges. Explosives would be used throughout the Study Area. Use of explosives is described in Section 3.0.3.3.2 (Explosive Stressors).

In general, explosive events would consist of a single explosion or a few smaller explosions over a short period, and would occur infrequently over the course of a year. With the exception of mine warfare, demolition charges, and line charge testing events that occur in shallow water close to shore (typically in the same locations that are regularly disturbed), most detonations would occur in areas with water depths greater than 200 ft. (but detonations still would occur at the surface) and greater than 3 NM from shore. Ship shock charges would occur off the continental shelf in water depths greater than 600 ft. As water depth increases away from shore, benthic invertebrates would be less likely to be impacted by detonations at or near the surface. The invertebrates that occur at or near the surface consist primarily of squid, jellyfish, and zooplankton, which are typically active near the surface at night, when explosions occur infrequently. In addition, detonations near the surface would release a portion of their explosive energy into the air, reducing the potential for impacts on pelagic invertebrates.

Mine warfare activities are typical examples of activities involving detonations on or near the bottom in nearshore waters. Invertebrates in these areas are adapted to frequent disturbance from storms and associated sediment redistribution. Studies of the effects of large-scale sediment disturbance such as dredging and sediment borrow projects have found recovery of benthic communities over a period of weeks to years (Posey & Alphin, 2002; U.S. Army Corps of Engineers, 2012). Recovery time is variable and may be influenced by multiple factors, but is generally faster in areas dominated by sand and moderate to strong water movement. The area of bottom habitat disturbed by explosions would be less than that associated with dredging or other large projects, and would occur mostly in soft bottom areas that are regularly disturbed by natural processes such as water currents and waves. It is therefore expected that areas affected by detonations would be recolonized rapidly (potentially within weeks) by recruitment from the surrounding invertebrate community. Craters resulting from detonations in the soft bottom would be filled and smoothed by waves and long-shore currents over time, resulting in no permanent change to bottom profiles that could affect invertebrate species assemblages. The time required to fill craters would depend on the size and depth, with deeper craters likely filling more slowly (U.S. Army Corps of Engineers, 2001). The amount of bottom habitat impacted by explosions would be a very small percentage of the habitat available in the Study Area. The total area of bottom habitat potentially disturbed by explosions is estimated at about 6.5 acres annually for testing activities.

In summary, explosives produce pressure waves that can harm invertebrates in the immediate vicinity of where the explosions occur. The majority of the explosions would occur in offshore surface waters where the predominant invertebrate species are prevalent mostly at night when testing activities typically occur infrequently. Exceptions occur where explosives are used on the bottom within nearshore or inshore waters on or near sensitive hard bottom communities that are currently not mapped or otherwise protected; shallow-water coral reefs are protected from such explosions whereas other live hard bottom communities are protected to the extent they are included in current mitigation measures. Soft bottom communities are resilient to occasional disturbances. Accordingly, the overall impacts of explosions on widespread invertebrate populations would likely be undetectable because of the small spatial and temporal scale of potential changes. Although individual marine invertebrates would likely be injured or killed during an explosion, the activities would be unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from explosives on seafloor resources in mitigation areas throughout the Study Area. For example, the Navy will not conduct explosive mine countermeasure and neutralization activities within a specified distance of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks. The mitigation will consequently also help avoid potential impacts on invertebrates that inhabit these areas, including several areas inhabited by white abalone and black abalone. In addition, procedural mitigations include the requirement to avoid jellyfish aggregations during the use of explosive torpedoes.

Black abalone are found primarily within the intertidal zone where explosions do not occur, but also occur in the subtidal zone to a depth of about 20 ft. White abalone occur at greater depth. Both species could potentially be exposed to underwater detonations associated with testing activities, although detonations are not expected to occur on the hard substrate or within the depth range associated with black abalone and white abalone. Because the number of underwater detonations is very small, the population density of black abalone and white abalone is very low, and detonations would not typically occur in areas likely to support black abalone and white abalone, the probability of these species being exposed to detonation effects is low. Navy activities would not overlap with designated black abalone critical habitat, and critical habitat has not been designated for white abalone under the ESA. Pursuant to the ESA, the use of explosives during testing activities as described under Alternative 1 would have no effect on designated black abalone critical habitat because activities would not occur within designated critical habitat, but may affect ESA-listed abalone species. The Navy has consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.4.3.2.2.2 Impacts from Explosives Under Alternative 2

Impacts from Explosives Under Alternative 2 for Training Activities

The locations, number of events, area affected, and potential effects associated with explosives would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.2.2.1 (Impacts from Explosives Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from explosives on seafloor resources in mitigation areas throughout the Study Area. For example, the Navy will not conduct explosive mine countermeasure and neutralization activities within a specified distance of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks. The mitigation will consequently also help avoid potential impacts on invertebrates that inhabit these areas, including several areas inhabited by white abalone and black abalone. In addition, procedural mitigations include the requirement to avoid jellyfish aggregations during sinking exercises and the use of explosive torpedoes.

As discussed in Section 3.4.3.2.2.1 (Impacts from Explosives under Alternative 1), pursuant to the ESA, the use of explosives during training activities as described under Alternative 2 may affect ESA-listed abalone species. The use of explosives would have no effect on black abalone critical habitat.

Impacts from Explosives Under Alternative 2 for Testing Activities

The locations of explosives use would be the same under Alternatives 1 and 2. The total area of bottom habitat potentially disturbed by explosions is estimated at about 8.0 acres annually, which represents a very small increase in the total area potentially disturbed in the Study Area compared to Alternative 1. However, the difference would not result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.2.2.1 (Impacts from Explosives Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from explosives on seafloor resources in mitigation areas throughout the Study Area. For example, the Navy will not conduct explosive mine countermeasure and neutralization activities within a specified distance of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks. The mitigation will consequently also help avoid potential impacts on invertebrates that inhabit these areas, including several areas inhabited by white abalone and black abalone. In addition, procedural mitigations include the requirement to avoid jellyfish aggregations during the use of explosive torpedoes.

As discussed in Section 3.4.3.2.2.1 (Impacts from Explosives Under Alternative 1), pursuant to the ESA, the use of explosives during testing activities as described under Alternative 2 may affect ESA-listed abalone species. The use of explosives would have no effect on black abalone critical habitat.

3.4.3.2.2.3 Impacts from Explosives Under the No Action Alternative

Impacts from Explosives Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Explosive stressors would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.3 Energy Stressors

This section analyzes the potential impacts of the various types of energy stressors that can occur during training and testing activities within the Study Area. This section includes analysis of the potential impacts from: (1) in-water electromagnetic devices, (2) in-air electromagnetic devices, and (3) high-energy lasers. Aspects of energy stressors that are applicable to marine organisms in general are presented in Section 3.0.3.6.2 (Conceptual Framework for Assessing Effects from Energy-Producing Activities).

3.4.3.3.1 Impacts from In-Water Electromagnetic Devices

Several different types of electromagnetic devices are used during training and testing activities. Information on the types of activities that use in-water electromagnetic devices is provided in Appendix B (Activity Stressor Matrices).

Little information is available regarding marine invertebrates' susceptibility to electromagnetic fields. Magnetic fields are not known to control spawning or larval settlement in any invertebrate species. Existing information suggests sensitivity to electric and magnetic fields in at least three marine invertebrate phyla: Mollusca, Arthropoda, and Echinodermata (Bureau of Ocean Energy Management, 2011; Lohmann et al., 1995; Lohmann & Lohmann, 2006). A possible magnetic sense has been suggested in jellyfish as well, although this has not been demonstrated experimentally (Fossette et al., 2015). Much of the available information on magnetic field sensitivity of marine invertebrates pertains to crustaceans. For example, a magnetic compass sense has been demonstrated in the spiny lobster (*Panulirus argus*) (Lohmann et al., 1995; Lohmann & Lohmann, 2006), and researchers suggest subtle behavioral response to magnetic fields of about 1 millitesla (1,000 microtesla) in the Dungeness crab and American lobster (Woodruff et al., 2013). A review of potential effects of undersea power cables on marine species provides a summary of numerous studies of the sensitivity of various invertebrate species to electric and magnetic fields (Bureau of Ocean Energy Management, 2011). Electric field sensitivity is reported in the summary for only two freshwater crayfish species, while magnetic field sensitivity is reported for multiple marine invertebrate species, including molluscs, crustaceans, and echinoderms. Sensitivity thresholds range from 300 to 30,000 microtesla, depending on the species. Most responses consisted of behavioral changes, although non-lethal physiological effects were noted in two sea urchin species in a 30,000 microtesla field (embryo development) and a marine mussel exposed to 300 to 700 microtesla field strength (cellular processes). Marine invertebrate community structure was not affected by placement of energized underwater power cables with field strengths of 73 to 100 microtesla (Love et al., 2016). Effects to eggs of the sea urchin *Paracentrotus lividus* and to brine shrimp (*Artemia* spp.) cysts have been reported at relatively high magnetic field strengths (750 to

25,000 microtesla) (Ravera et al., 2006; Shckorbatov et al., 2010). The magnetic field generated by the Organic Airborne and Surface Influence Sweep (a typical electromagnetic device used in Navy training and testing) is about 2,300 microtesla at the source. Field strength drops quickly with distance from the source, decreasing to 50 microtesla at 4 m, 5 microtesla at 24 m, and 0.2 microtesla at 200 m from the source. Therefore, temporary disruption of navigation and directional orientation is the primary impact considered in association with magnetic fields.

Studies of the effects of low-voltage direct electrical currents in proximity to marine invertebrates suggest a beneficial impact on at least some species at appropriate current strength. American oysters (*Crassostrea virginica*) and various stony and soft corals occurring on substrates exposed to low-voltage currents (between approximately 10 and 1,000 microamperes) showed increased growth rates and survival (Arifin et al., 2012; Goreau, 2014; Jompa et al., 2012; Shorr et al., 2012). It is theorized that the benefits may result from a combination of more efficient uptake of calcium and other structure-building minerals from the surrounding seawater, increased cellular energy production, and increased pH near the electrical currents. The beneficial effects were noted in a specific range of current strength; higher or lower currents resulted in either no observable effects or adverse effects. The moderate voltage and current associated with the Organic Airborne and Surface Influence Sweep are not expected to result in adverse effects to invertebrates. In addition, due to the short-term, transient nature of electromagnetic device use, there would be no beneficial effects associated with small induced electrical currents in structures colonized by invertebrates.

3.4.3.3.1.1 Impacts from In-Water Electromagnetic Devices Under Alternative 1

Impacts from In-Water Electromagnetic Devices Under Alternative 1 for Training Activities

As indicated in Section 3.0.3.3.3.1 (In-Water Electromagnetic Devices), under Alternative 1, training activities involving in-water electromagnetic devices would occur in the Southern California Range Complex.

The impact of electromagnetic devices to marine invertebrates would depend upon the sensory capabilities of a species and the life functions that its' magnetic or electric sensory systems support (Bureau of Ocean Energy Management, 2011). The primary potential effect would be temporary directional disorientation for individuals encountering a human-produced magnetic field. For example, an individual could be confused or change its movement direction while exposed to a field. However, a limited number of studies suggest other effects, such as changes in embryo development, are possible within relatively strong fields for an extended time (10 to 150 minutes). Electromagnetic devices used in Alternative 1 would only affect marine invertebrates located within a few feet of the source. In addition, most electromagnetic devices are mobile and would produce detectable magnetic fields for only a short time at any given location. Further, due to the exponential drop in field strength with distance and the fact that electromagnetic devices are operated in the water column away from the bottom, it is unlikely that benthic invertebrates such as lobsters and crabs would be affected. For example, operation of the Organic Airborne and Surface Influence Sweep in 13 ft. water depth would produce field strength at the bottom that is an order of magnitude lower than any field strength associated with behavioral or physiological effects in the available study reports. Therefore, exposed species would be those typically found in the water column such as jellyfish, squid, and zooplankton, and mostly at night when squid and zooplankton have migrated up in the water column. Although a small number of invertebrates would be exposed to electromagnetic fields, exposure is not expected to yield any lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

The ESA-listed black abalone and white abalone occur in the Southern California Range Complex. However, the use of in-water electromagnetic devices would not expose ESA-listed abalone species to electromagnetic fields because the devices would be operated in relatively deep water, and the field strength drops rapidly with distance from the source. There is no overlap of electromagnetic device use in the Southern California Range Complex in designated black abalone critical habitat. Therefore, electromagnetic devices would not affect black abalone critical habitat. Critical habitat has not been designated for white abalone under the ESA. Pursuant to the ESA, the use of in-water electromagnetic devices during training activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from In-Water Electromagnetic Devices Under Alternative 1 for Testing Activities

As indicated in Section 3.0.3.3.3.1 (In-Water Electromagnetic Devices), under Alternative 1, testing activities involving in-water electromagnetic devices would occur in the Hawaii Range Complex and Southern California Range Complex.

The impact of electromagnetic devices to marine invertebrates would depend upon the sensory capabilities of a species and the life functions that its' magnetic or electric sensory systems support (Bureau of Ocean Energy Management, 2011). The primary potential effect would be temporary directional disorientation for individuals encountering a human-produced magnetic field. For example, an individual could be confused or change its movement direction while exposed to a field. However, a limited number of studies suggest other effects such as changes in embryo development are possible within relatively strong fields for an extended time (10 to 150 minutes). Electromagnetic devices used in Alternative 1 would only affect marine invertebrates located within a few feet of the source. In addition, most electromagnetic devices are mobile and would produce detectable magnetic fields for only a short time at any given location. Further, due to the exponential drop in field strength with distance and the fact that electromagnetic devices are operated in the water column away from the bottom, it is unlikely that benthic invertebrates such as lobsters and crabs would be affected. For example, operation of the Organic Airborne and Surface Influence Sweep in 13 ft. water depth would produce field strength at the bottom that is an order of magnitude lower than any field strength associated with behavioral or physiological effects in the available study reports. Therefore, exposed species would be those typically found in the water column such as jellyfish, squid, and zooplankton, and mostly at night when squid and zooplankton have migrated up in the water column. Although a small number of invertebrates would be exposed to electromagnetic fields, exposure is not expected to yield any lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

The ESA-listed black abalone and white abalone occur in the Southern California Range Complex. However, the use of in-water electromagnetic devices would not expose ESA-listed abalone species to electromagnetic fields because the devices would be operated in relatively deep water, and the field strength drops rapidly with distance from the source. There is no overlap of electromagnetic device use in the Southern California Range Complex in designated black abalone critical habitat. Therefore, electromagnetic devices would not affect black abalone critical habitat. Critical habitat has not been designated for white abalone under the ESA. Pursuant to the ESA, the use of in-water electromagnetic devices during testing activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.3.1.2 Impacts from In-Water Electromagnetic Devices Under Alternative 2

Impacts from In-Water Electromagnetic Devices Under Alternative 2 for Training Activities

The locations, number of events, and potential effects associated with in-water electromagnetic devices would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.3.1.1 (Impacts from In-Water Electromagnetic Devices Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.3.1.1 (Impacts from In-Water Electromagnetic Devices Under Alternative 1), pursuant to the ESA, the use of in-water electromagnetic devices during training activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from In-Water Electromagnetic Devices Under Alternative 2 for Testing Activities

The locations, number of events, and potential effects associated with in-water electromagnetic devices would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.3.1.1 (Impacts from In-Water Electromagnetic Devices Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.3.1.1 (Impacts from In-Water Electromagnetic Devices Under Alternative 1), pursuant to the ESA, the use of in-water electromagnetic devices during testing activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.3.1.3 Impacts from In-Water Electromagnetic Devices Under the No Action Alternative

Impacts from In-Water Electromagnetic Devices Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various energy stressors (e.g., in-water electromagnetic devices) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.3.2 Impacts from In-Air Electromagnetic Devices

In-air electromagnetic devices are not applicable to invertebrates because of the lack of transmission of electromagnetic radiation across the air/water interface and will not be analyzed further in this section.

3.4.3.3.3 Impacts from High-Energy Lasers

This section analyzes the potential impacts of high-energy lasers on invertebrates. As discussed in Section 3.0.3.3.3.3 (Lasers), high-energy laser weapons are designed to disable surface targets, rendering them immobile. The primary concern is the potential for an invertebrate to be struck with the laser beam at or near the water's surface, where extended exposure could result in injury or death.

Marine invertebrates could be exposed to the laser only if the beam misses the target. Should the laser strike the sea surface, individual invertebrates at or near the surface, such as jellyfish, floating eggs, and larvae, could potentially be exposed. The potential for exposure to a high-energy laser beam decreases rapidly as water depth increases and with time of day, as many zooplankton species migrate away from the surface during the day. Most marine invertebrates are not susceptible to laser exposure because they occur beneath the sea surface.

3.4.3.3.3.1 Impacts from High-Energy Lasers Under Alternative 1

Impacts from High-Energy Lasers Under Alternative 1 for Training Activities

There would be no use of high-energy lasers associated with training activities. Therefore, high-energy lasers are not analyzed in this subsection.

Impacts from High-Energy Lasers Under Alternative 1 for Testing Activities

As indicated in Section 3.0.3.3.3.3 (Lasers) under Alternative 1, testing activities involving high-energy lasers would occur in the Hawaii Range Complex and Southern California Range Complex.

Invertebrates that do not occur at or near the sea surface would not be exposed due to the attenuation of laser energy with depth. Surface invertebrates such as squid, jellyfish, and zooplankton (which may include invertebrate larvae) exposed to high-energy lasers could be injured or killed, but the number of individuals potentially impacted would be low based on the relatively low number of events, very localized potential impact area of the laser beam, and the temporary duration (seconds) of potential impact. Activities involving high-energy lasers are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level because of the relatively small number of individuals that could be impacted.

Benthic invertebrates, including ESA-listed abalone species, would not be affected by high-energy lasers. In addition, high-energy lasers would not affect essential biological features of black abalone critical habitat. Critical habitat has not been designated for white abalone under the ESA. Pursuant to the ESA, the use of high-energy lasers during training activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.3.3.2 Impacts from High-Energy Lasers Under Alternative 2

Impacts from High-Energy Lasers Under Alternative 2 for Training Activities

There would be no use of high-energy lasers associated with training activities. Therefore, high-energy lasers are not analyzed in this subsection.

Impacts from High-Energy Lasers Under Alternative 2 for Testing Activities

The locations, number of events, and potential effects associated with high-energy lasers would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.3.3.1 (Impacts from High-Energy Lasers Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.3.3.1 (Impacts from High-Energy Lasers Under Alternative 1), pursuant to the ESA, the use of high-energy lasers during testing activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.3.3.3 Impacts from High-Energy Lasers Under the No Action Alternative

Impacts from High-Energy Lasers Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed testing activities in the HSTT Study Area. High-energy laser use is not a part of ongoing Navy activities in the Study Area and this energy stressor would not be introduced into the marine environment under the No Action Alternative. Therefore, no change in baseline conditions of the existing environment would occur.

3.4.3.4 Physical Disturbance and Strike Stressors

This section analyzes the potential impacts of the various types of physical disturbance and strike stressors that could result from Navy training and testing activities within the Study Area. For a list of locations and numbers of activities that may cause physical disturbance and strikes refer to Section 3.0.3.3.4 (Physical Disturbance and Strike Stressors). Aspects of physical disturbance and strike stressors that are applicable to marine organisms in general are presented in Section 3.0.3.6.3 (Conceptual Framework for Assessing Effects from Physical Disturbance or Strike). The physical disturbance and strike stressors that may impact marine invertebrates include: (1) vessels and in-water devices, (2) military expended materials, (3) seafloor devices, and (4) pile driving.

Most marine invertebrate populations extend across wide areas containing hundreds or thousands of discrete patches of suitable habitat. Sessile invertebrate populations may be connected by complex currents that carry adults and young from place to place. Impacts on such widespread populations are difficult to quantitatively evaluate in terms of Navy training and testing activities that occur intermittently and in relatively small patches in the Study Area. Invertebrate habitats generally cover enormous areas (Section 3.5, Habitats) and, in this context, a physical strike or disturbance would impact individual organisms directly or indirectly, but not to the extent that viability of populations of common species would be impacted. While the potential for overlap between Navy activities and invertebrates is reduced for those species living in rare habitats, if overlap does occur, any potential impacts would be amplified for those invertebrate species or taxa with limited spatial extent. Examples of such organisms include abalones, stony corals, and sponges, which are mostly restricted to hard bottom habitat or artificial habitat. Shallow-water coral reefs, precious coral beds, live hard bottom, and other areas of hard substrate such as artificial reefs are protected to the extent they are included in current mitigation measures.

With few exceptions, activities involving vessels and in-water devices are not intended to contact the bottom due to potential damage to equipment and the resulting safety risks for vessel personnel. The potential for strike impact and disturbance of benthic or habitat-forming marine invertebrates would result from amphibious activities, bottom-crawling unmanned underwater vehicles, military expended materials, seafloor devices, and pile driving. For environmental and safety reasons, amphibious landings and other nearshore activities would avoid areas where corals are known to occur.

With the exception of habitat-forming benthic taxa (e.g., corals, sea pens, and sponges), most small invertebrate populations recover quickly from non-extractive disturbance. Many large invertebrates, such as crabs, shrimps, and clams, undergo massive disturbance during commercial and recreational harvests, storms, or beach restoration activities. Invertebrates that occur in the high-energy surf zone are typically resilient to dynamic processes of sediment erosion and accretion, although some community effects may occur due to rapid and relatively large-scale changes such as those associated with beach renourishment projects (U.S. Army Corps of Engineers, 2001).

Biogenic habitats such as shallow coral reefs, deep-water coral, and sponge communities may take decades to regrow following a strike or disturbance (Jennings & Kaiser, 1998; Precht et al., 2001). However, bottom-disturbing activities are not conducted on mapped coral reefs or live hard bottom. In soft bottom areas, recovery of benthic invertebrate populations after substantial human disturbance depends on factors such as size of the area disturbed, bottom topography, hydrodynamics of the affected area, seasonality of the disturbance, and the size and typical growth rate of affected species. Most studies of the effects of beach sand nourishment projects (which is a proxy for impacts due to amphibious landings) have reported initial declines in benthic invertebrate populations due to burial and increased turbidity (which may affect filter-feeding capability), but subsequent recovery over time scales of weeks to years (Posey & Alphin, 2002; U.S. Army Corps of Engineers, 2001, 2012; Wilber et al., 2009). Recovery is typically greatest at nourishment sites when there is a close match in grain size between the existing and supplied sediment. However, species composition may be altered in the recolonized area, and overall invertebrate biomass may not recover for many years. Researchers found that trawling off the California coast resulted in no statistical difference in the abundance of sessile or mobile benthic invertebrates (Lindholm et al., 2013). However, repeated and intense bottom fishing disturbance can result in a shift from communities dominated by relatively high-biomass individuals towards dominance by high abundance of small-sized organisms (Kaiser et al., 2002). If activities are repeated at the same site, the benthic invertebrate community composition could be altered over time (years), especially for sessile invertebrates (e.g., coral). Some bottom-disturbing activities, such as mine countermeasures and neutralization training and testing, precision anchoring, and placement of the Elevated Causeway System, may occur in the same locations or near the same locations yearly.

3.4.3.4.1 Impacts from Vessels and In-Water Devices

Vessels

The majority of the training and testing activities under all the alternatives involve vessels. For a discussion of the types of activities that use vessels and where they are used, refer to Appendix B (Activity Stressor Matrices). See Table 3.0-15 for a representative list of Navy vessel types, lengths, and speeds.

Vessels could impact adults and other life stages of marine invertebrates by directly striking organisms, or by disturbing the water column or sediments (Bishop, 2008). Species that occur at or near the surface (e.g., jellyfish, squid) would potentially be exposed to direct vessel strikes. Exposure to propeller-generated turbulence was found to result in mortality in a zooplankton species (the copepod *Acartia tonsa*) located near the surface (Bickel et al., 2011). However, many pelagic invertebrates such as squid and zooplankton move away from the surface during the day, reducing potential exposures during daytime vessel operations. Many vessel hulls have a hydrodynamic shape, and pelagic marine invertebrates are therefore generally disturbed, rather than struck, as the water flows around a vessel. Zooplankton are ubiquitous in the water column and typically experience high mortality rates.

In addition, vessel hull strikes and propeller cavitation and turbulence could displace, damage, injure, or kill invertebrate eggs and larvae in the upper portion of the water column throughout the Study Area. For example, turbulent water was found to decrease successful fertilization and resulted in abnormal development and low survival in eggs of the broadcast spawning purple sea urchin (*Strongylocentrotus purpuratus*) (Mead & Denny, 1995). In some areas of the Hawaii Range Complex, vessels could transit through water containing coral gametes, eggs, embryonic stages, or planula larvae of broadcast spawning species. Eggs of cluster coral (*Acropora millepora*) were found to disintegrate into irregular groups or individual blastomeres when subjected to even very light shearing forces and turbulence (Heyward & Negri, 2012). Such dissociation can be beneficial through creation of more juveniles, but may also cause mortality. Early embryonic development of broadcast spawning coral species has reportedly been affected by handling of captive-reared embryos (Guest et al., 2010). Although the available information indicates that developmental stages of numerous invertebrate species could be physically impacted, broadcast-spawning invertebrates produce very large numbers of eggs and planktonic larvae that typically experience high mortality rates under normal conditions (Nybakken, 1993). Any impacts resulting from Navy vessel operation would be biologically insignificant by comparison.

Propeller wash (water displaced by propellers used for propulsion) of even the deepest draft vessels operated over the continental shelf is likely indistinguishable from the water motion associated with periodic storm events, and vessel operation in deeper waters beyond the shelf break would not affect the bottom. Therefore, the potential for vessels to disturb invertebrates on or near the bottom would occur mostly during nearshore and inshore training or testing activities, and along dredged navigation channels. Invertebrates on or near the bottom in such relatively shallow areas could be affected by sediment disturbance or direct strike during amphibious landings. Few sources of information are available on the impact of non-lethal chronic vessel disturbance to marine invertebrates. One study of seagrass-associated marine invertebrates, such as amphipods and polychaetes, found that chronic disturbance from vessel wakes resulted in the long-term displacement of some marine invertebrates from the impacted shallow-water area (Bishop, 2008). However, invertebrates that typically occur in areas associated with nearshore or inshore activities, such as shorelines, are highly resilient to vessel disturbance. They are regularly disturbed by natural processes such as high-energy waves and longshore currents, and generally recover quickly. Potential exceptions include sessile or encrusting invertebrates that may occur along sheltered shorelines that are subject to a high frequency of boat propeller- or wake-induced erosion (Grizzle et al., 2002; Zabawa & Ostrom, 1980). Increased erosion of shoreline banks or suspension of bottom sediments may cause turbidity that affects filter-feeding invertebrates. The results of a small number of studies suggest that the wave energy resulting from boat wakes produced in relatively narrow water bodies may affect oyster occurrence, and studies of shallow freshwater areas found that waves generated from small boats caused about 10 percent of benthic invertebrates (e.g., amphipods) to become suspended in the water column where they presumably would be more vulnerable to predation (Bilkovic et al., 2017).

Non-amphibious vessels avoid contact with the bottom in order to prevent damage to the vessels and benthic habitat that supports encrusting organisms. The encrusting organisms (e.g., hard corals) living on hard substrate in the ocean are exposed to strong currents under natural conditions and would not likely be affected by propeller wash. Many activities occur in offshore areas and, therefore, would be unlikely to affect benthic invertebrates, although small-caliber gunnery exercises, blank firing, and smoke grenade use may occur in areas closer to shore. Many Navy vessel movements in nearshore waters are concentrated in established channels and ports or predictable transit corridors between the Hawaiian Islands or between San Diego Bay and San Clemente Island, and shallow-water vessels typically operate in defined boat lanes with sufficient depths to avoid propeller or hull strikes on the bottom.

The only source of shallow-water vessel movement in the Study Area with known direct impacts on benthic invertebrates is amphibious landings, which are conducted in the Silver Strand Training Complex, Hawaii Range Complex, and Southern California Range Complex (Appendix A, Navy Activity Descriptions). Amphibious vessels would contact the bottom in the surf zone during amphibious assault and amphibious raid operations. Benthic invertebrates of the surf zone, such as crabs, clams, and polychaete worms, within the disturbed area could be displaced, injured, or killed during amphibious operations. Burrowing species such as ghost shrimp are present on many beaches, and individuals in relatively shallow burrows located just above harder sand layers could be injured or killed if amphibious vessels compress the sand above them. Passage of amphibious vessels could cause some elevated turbidity in the nearshore zone seaward of the surf zone. However, the sediment along landing beaches is constantly being reworked by nearshore wave energy and, to a lesser extent (although more frequently than disturbance caused by amphibious landings), storm events. Benthic invertebrates inhabiting these areas are adapted to a naturally disturbed environment and are expected to rapidly re-colonize similarly disturbed areas by immigration and larval recruitment. Studies indicate that benthic communities of high-energy sandy beaches recover relatively quickly (typically within 2 to 7 months) following beach nourishment. Researchers found that the macrobenthic (visible organisms on the bottom) community required between 7 and 16 days to recover following excavation and removal of sand from a 200 m^2 quadrant from the intertidal zone of a sandy beach (Schoeman et al., 2000). The number of invertebrates impacted during amphibious landings would be small compared to the number that are affected during activities such as beach nourishment. The impacts of amphibious vehicle operations on benthic communities would therefore likely be minor, short term, and local.

Other than organisms occurring at amphibious landing sites, invertebrates that occur on the bottom, including shallow-water corals, organisms associated with hard bottom, and deep-water corals, are not likely to be exposed to vessel strikes. Propeller movement has the potential to disrupt sediments that could affect shallow-water corals and hard bottom communities. However, shallow-water corals and abalone species do not occur along the shoreline adjacent to amphibious landing areas.

In-Water Devices

Some of the training and testing activities under both action alternatives involve the use of in-water devices, including remotely operated vehicles, unmanned surface vehicles, unmanned underwater vehicles, motorized autonomous targets, and towed devices. For a discussion of the types of activities that use in-water devices, see Appendix B (Activity Stressor Matrices). See Table 3.0-17 for the types, sizes, and speeds of representative Navy in-water devices used in the Study Area.

In-water devices can operate from the water's surface to the benthic zone. The devices could potentially impact marine invertebrates by directly striking organisms or by disturbing the water column. As discussed for vessel use, most invertebrates in the water column would be disturbed, rather than struck, as water flows around a device due to the hydrodynamic shape. In addition, in-water devices are smaller than most Navy vessels, decreasing the surface area in which invertebrates could be struck. The potential for direct strike is reduced for some types of devices because they are operated at relatively low speeds (e.g., unmanned underwater vehicles, which are typically operated at speeds of 1 to 15 knots). Unmanned surface vehicles are operated at the greatest speeds (up to 50 knots or more) and therefore have greater potential to strike invertebrates. However, relatively few invertebrates occur at the surface and consist mostly of squid, jellyfish, and zooplankton. Squid and many zooplankton species move away from the surface during the day (Nybakken, 1993), when unmanned surface vehicles are typically operated. In-water devices do not normally collide with invertebrates on the bottom because the devices are operated in relatively deep water and contact with the bottom is avoided. Devices operated very near the bottom could potentially disturb sediments and associated invertebrates through propeller wash. However, such disturbance would be infrequent and would affect a small area, and disturbed areas would be quickly reoccupied by benthic invertebrates.

As discussed for vessels, zooplankton and invertebrate eggs and larva could be displaced, damaged, injured, or killed by propeller wash or turbulence resulting from water flow around in-water devices. Effects due to turbulence would generally increase with increasing speed of the device. Many zooplankton species migrate away from the surface during the day, when Navy training and testing typically are conducted, decreasing the potential for impacts in the upper portions of the water column.

The number of individuals affected would be small in comparison to overall populations, and the affected species generally exhibit rapid growth and recovery rates.

3.4.3.4.1.1 Impacts from Vessels and In-Water Devices Under Alternative 1

Impacts from Vessels and In-Water Devices Under Alternative 1 for Training Activities

The number and location of activities that include vessels is shown in Table 3.0-16, and the number and location of activities that include in-water devices is shown in Table 3.0-18. The majority of Navy training activities include vessels, while a lower number of activities include in-water devices. As indicated in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), vessel operation would be widely dispersed throughout the Study Area but would be more concentrated near ports, naval installations, and range complexes. Most vessel use would occur in the Southern California Range Complex. Amphibious landings could occur at designated beaches in the Study Area. Hydrographic surveys have been used to map precise transit routes through sandy bottom areas to avoid potential vessel strikes of corals in the Hawaii Range Complex.

Similar to vessel operation, activities involving in-water devices could be widely dispersed throughout the Study Area, but would be more concentrated near naval ports, piers, and ranges. Training activities would occur in the Hawaii Range Complex, Southern California Range Complex, and HSTT Transit Corridor. Most in-water device use would occur in the Southern California Range Complex.

As discussed in Section 3.4.3.4.1 (Impacts from Vessels and In-Water Devices), invertebrates located at or near the surface could be struck or disturbed by vessels, and invertebrates throughout the water column could be similarly affected by in-water devices. There would be a higher likelihood of vessel and in-water device strikes over the continental shelf than in the open ocean portions of the Study Area because of the concentration of activities and comparatively higher abundances of invertebrates in areas closer to shore. However, direct strikes would generally be unlikely for most species. Exceptions would include amphibious landings, where vessels contact the bottom and may directly impact invertebrates. Organisms inhabiting these areas are expected to rapidly re-colonize disturbed areas. Other than during amphibious landings, purposeful contact with the bottom by vessels and in-water devices would be avoided. The potential to disturb invertebrates on or near the bottom would occur mostly during vessel nearshore and onshore training activities, and along dredged navigation channels. Invertebrates that typically occur in areas associated with nearshore or onshore activities, such as shorelines, are highly resilient to vessel disturbance. Propeller wash and turbulent water flow could damage or kill zooplankton and invertebrate gametes, eggs, embryonic stages, or larvae. Overall, the area exposed to vessel and in-water device disturbance would be a very small portion of the surface and water column in the Study Area, and only a small number of individuals would be affected compared to overall abundance. Therefore, the impact of vessels and in-water devices on marine invertebrates would be inconsequential. Activities are not expected to yield any lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

Species that do not occur near the surface within the Study Area, including ESA-listed black abalone and white abalone, would not be exposed to vessel strikes. In addition, these species would not be affected by amphibious landings (amphibious assault, insertion, and extraction) since abalone inhabit rocky shores and hard bottom, which are not used for amphibious landings. In-water devices do not contact the bottom and would therefore not impact black abalone or white abalone. Navy activities would not occur in designated black abalone critical habitat, and critical habitat has not been designated for white abalone under the ESA. Pursuant to the ESA, the use of vessels and in-water devices during training activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Vessels and In-Water Devices Under Alternative 1 for Testing Activities

The number and location of activities that include vessels and in-water devices is shown in Table 3.0-16. As indicated in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), vessel operation would be widely dispersed throughout the Study Area, but would be more concentrated near ports, naval installations, testing ranges, and range complexes. Vessel movements would occur throughout the Study Area but would be concentrated in the Southern California Range Complex. Similarly, as indicated in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), in-water devices would be used throughout the Study Area (including the Transit Corridor) but would be concentrated in the Southern California Range Complex.

As discussed in Section 3.4.3.4.1 (Impacts from Vessels and In-Water Devices), invertebrates located at or near the surface could be struck or disturbed by vessels, and invertebrates throughout the water column could be similarly affected by in-water devices. There would be a higher likelihood of vessel and in-water device strikes over the continental shelf than in the open ocean portions of the Study Area because of the concentration of activities in those areas. However, direct strikes would generally be unlikely for most species, particularly for benthic invertebrates due to the absence of amphibious landings. Purposeful contact with the bottom would be avoided. Propeller wash and turbulent water flow could damage or kill zooplankton and invertebrate gametes, eggs, embryonic stages, or larvae. Overall, the area potentially exposed to vessel and in-water device disturbance is a very small portion of the surface and water column in the Study Area, and only a small number of individuals would be affected compared to overall abundance. The impact of vessels and in-water devices on marine invertebrates would be inconsequential. Activities are not expected to yield any lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

Species that do not occur near the surface within the Study Area, including ESA-listed black abalone and white abalone, would not be exposed to vessel strikes. In addition, in-water devices do not contact the bottom and would therefore not impact these abalone species. Navy activities would not occur in designated black abalone critical habitat, and critical habitat has not been designated for white abalone under the ESA. Pursuant to the ESA, the use of vessels and in-water devices during testing activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.4.1.2 Impacts from Vessels and In-Water Devices Under Alternative 2

Impacts from Vessels and In-Water Devices Under Alternative 2 for Training Activities

Under Alternative 2, potential impacts on invertebrates resulting from vessels and in-water devices associated with training activities would be similar to those discussed for activities under Alternative 1. There would be a very small increase in vessel and in-water device use in the Study Area. However, the difference would not result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.4.1.1 (Impacts from Vessels and In-Water Devices Under Alternative 1) for a discussion of potential impacts.

As discussed in Section 3.4.3.4.1.1 (Impacts from Vessels and In-Water Devices Under Alternative 1), pursuant to the ESA, the use of vessels and in-water devices during training activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Vessels and In-Water Devices Under Alternative 2 for Testing Activities

Under Alternative 2, potential impacts on invertebrates resulting from vessels and in-water devices associated with testing activities would be similar to those discussed for activities under Alternative 1. There would be a very small increase in vessel and in-water device use in the Study Area. However, the difference in vessel use would not result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.4.1.1 (Impacts from Vessels and In-Water Devices Under Alternative 1) for a discussion of potential impacts.

As discussed in Section 3.4.3.4.1.1 (Impacts from Vessels and In-Water Devices Under Alternative 1), pursuant to the ESA, the use of vessels and in-water devices during testing activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.4.1.3 Impacts from Vessels and In-Water Devices Under the No Action Alternative

Impacts from Vessels and In-Water Devices Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various physical disturbance and strike stressors (e.g., vessels and in-water devices) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.4.2 Impacts from Aircraft and Aerial Targets

Impacts from aircraft and aerial targets are not applicable because marine invertebrates do not occur in airborne environments and will not be analyzed further in this section. Refer to Section 3.4.3.4.3 (Impacts from Military Expended Materials) for potential disturbance from fragments of aircraft and aerial targets.

3.4.3.4.3 Impacts from Military Expended Materials

This section analyzes the strike potential to marine invertebrates from the following categories of military expended materials: (1) all sizes of non-explosive practice munitions, (2) fragments from high-explosive munitions, (3) expendable targets and target fragments, and (4) expended materials other than munitions, such as sonobuoys, expended bathythermographs, and torpedo accessories. For a discussion of the types of activities that use military expended materials, refer to Appendix B (Activity Stressor Matrices). For a discussion on where they are used and how many exercises would occur under each alternative, see Appendix F (Military Expended Material and Direct Strike Impact Analyses) and Section 3.0.3.3.4.2 (Military Expended Materials). Analysis of all potential impacts of military expended materials (disturbance, strike, shading, and abrasion) on invertebrates, including ESA-listed black abalone and white abalone, is included in this section. Potential impacts of military expended materials resulting from entanglement and ingestion are discussed in Section 3.4.3.5 (Entanglement Stressors) and Section 3.4.3.6 (Ingestion Stressors).

Military expended materials are deposited throughout the Study Area. However, the majority of military expended materials are deposited within established range complexes and testing ranges. These areas of higher military expended materials deposition are generally located away from the coastline on the continental shelf and slope and beyond (e.g., abyssal plain). Physical disturbance or strikes by military expended materials on marine invertebrates is possible at the water's surface, through the water column, and on the bottom. However, disturbance or strike impacts on marine invertebrates by military expended materials falling through the water column are not very likely because military expended materials do not generally sink rapidly enough to cause strike injury. Exposed invertebrates would likely experience only temporary displacement as the object passes by. Therefore, the discussion of military expended materials disturbance and strikes will focus on items at the water's surface and on the bottom.

Potential impacts on invertebrates generally consist of physical trauma, stress or behavioral responses, abrasion, and shading. Military expended materials may injure or kill invertebrates by directly striking individuals, causing breakage (particularly for species with exoskeletons or that build structures), crushing, or other physical trauma. Direct strike may result from the initial impact, or may occur after items fall through the water column and settle onto invertebrates or are moved along the bottom by water currents or gravity. Expended items may also bury or smother organisms although, depending on the size of the expended item relative to the animal, some mobile invertebrates may be able to move or dig out from underneath an item. In addition to physical strike, military expended materials may disturb individuals and cause them to change locations, behaviors, or activities. Disturbance could therefore result in impacts such as briefly increased energy expenditure, decreased feeding, and increased susceptibility to predation. Expended items could also cause increased turbidity that could affect filter-feeding species, although such impacts are likely to be localized and temporary. Expended items that come to rest on or near corals could cause abrasion or shading (in the case of corals that host symbiotic algae) that reduces photosynthesis in the algae, although these effects are unlikely based on the mitigation measures in place for shallow-water coral reefs where symbiotic algae are present. Abrasion refers to scraping or wearing down of a supporting structure or hard body part (e.g., coral skeleton, shell) through repeated impact on the same individual or structure. Abrasion would generally be associated with military expended materials such as flexible materials (e.g., wires or cords) that become fixed in a location for some time but that are moved repeatedly over sessile invertebrates by water currents.

Military expended materials that impact the water surface could directly strike zooplankton, the gametes, embryos, and larvae of various invertebrate species (including ESA-listed abalone species), and a small number of adult invertebrates (e.g., squid, jellyfish, swimming crabs). However, many zooplankton and squid are absent from the surface water column during the day when most training and testing activities occur. Inert military expended materials also have the potential to impact the water and produce a large impulse which could disturb nearby invertebrates. Potential impacts on invertebrates resulting from impulsive sound and shock waves are discussed in Section 3.4.3.1 (Acoustic Stressors) and Section 3.4.3.2 (Explosive Stressors). In addition to direct strike of invertebrates and production of impulsive sound, surface water impacts could affect physical properties of the surrounding water (e.g., slight heating or increased dissolved gas concentrations due to turbulent mixing with the atmosphere), potentially affecting the suitability of the affected water mass as habitat for some invertebrate species. However, physical changes to the water column would be localized and temporary, persisting for only a few minutes.

Compared to surface waters and offshore areas, a greater number of macroinvertebrates typically occurs on the bottom and closer to shore. Benthic invertebrate taxa, including sponges, cnidarians, worms, bryozoans, molluscs, arthropods, and echinoderms, may occur in areas affected by military expended materials. However, some of the most sensitive benthic species (e.g., corals) are more likely to occur on hard bottom, reefs, and other hard substrates. Shallow-water coral reefs are protected by mitigation measures from most activities that generate military expended materials. Military expended materials that impact the bottom may affect invertebrates by strike (including injury or mortality), disturbance, burial, abrasion, or shading within the footprint of the item (the area of substrate physically covered by the item). Military expended materials may also cause physiological or behavioral reactions to individual invertebrates outside the footprint of the items. After items come to rest on the bottom, continued impacts are possible if the items are mobilized by currents or waves and damage benthic invertebrates as they move. Turbidity may also occur as water flows around deposited items. However, these impacts would generally cease when the military expended materials are incorporated into the seafloor by natural encrustation or burial processes, or become otherwise immobilized.

Sessile marine invertebrates and infauna (organisms attached to the bottom or living in the sediments) are generally more susceptible to military expended material disturbance and strike than benthic species with the ability to move relatively quickly over the bottom. Some susceptible species (e.g., hydroids, sponges, soft corals) have fragile structures and sensitive body parts that could be damaged or covered by military expended materials. Military expended materials could also break hard structures such as coral skeletons and mussel beds. Shallow- and deep-water corals that build complex or fragile structures could be particularly susceptible to breakage or abrasion. Such structures are resistant to physical forces typical of ambient conditions (e.g., water currents), but not as resilient to other types of physical disturbance involving greater force. Decelerators/parachutes would be unlikely to be carried by currents onto reef structures due to the typical offshore locations of use and the sink rate of the items. Expended items may provide new colonization sites for benthic invertebrates. Researchers found that military expended materials in a bombing range became covered by sedentary reef invertebrates over time (Smith & Marx, 2016). However, invertebrate species composition on artificial substrates may differ from that of the surrounding natural community.

Potential impacts on shallow-water corals, invertebrates associated with hard bottom habitat, or deep-water corals present the greatest risk of long-term damage compared with other bottom communities because: (1) many corals and hard bottom invertebrates are sessile, fragile, and particularly vulnerable; (2) many of these organisms grow slowly and could require decades to recover; and (3) military expended materials are likely to remain exposed on hard bottom communities whereas shifting sediment patterns would tend to bury military expended materials in soft bottom communities. The probability of striking deep-water corals or invertebrates located on hard bottom habitat is low, given their low percent cover on suitable habitat (see Section 3.5.2.1.2, Bottom Habitats, for a discussion of hard bottom habitat).

A few investigations have been conducted to determine the presence and, in some cases, possible impacts of military expended materials on the bottom. The results of multi-year underwater surveys at a military bombing range in the Mariana Archipelago (Pacific Ocean) provide an example of potential impacts resulting from expended munitions. Water areas were not targeted at this range; bottom impacts occurred only when the target land mass was missed or the munition bounced off the land into the water. The surveys found no overall long-term adverse impacts on corals or other invertebrates due to expended items, despite several decades of use (Smith & Marx, 2016). Numerous intact bombs and fragments were observed on the bottom. Inert 500 lb. bombs were found to disturb a bottom area of 17 m^2 each, although specific damage to invertebrates, if any, was not described. It may be presumed that invertebrates within this footprint could have been killed, injured, damaged, or displaced. Expended items, once settled in place, appeared to become encrusted with marine growth and pose no substantial long-term threat to invertebrates. The condition of corals indicated a healthy environment, with no apparent change in species composition, distribution, size, or stress indicators. However, the results of several other studies indicate that sessile invertebrate communities growing on artificial substrate such as the expended munitions are often different than those growing on natural substrate (Burt et al., 2009; Macreadie et al., 2011; Perkol-Finkel et al., 2006; Steimle & Zetlin, 2000). A remotely operated vehicle survey of deep portions of the Jacksonville Range Complex reported only two exposed items of military expended materials in about 37,800 m of survey line distance (U.S. Department of the Navy, 2010, 2011). However, it is important to note that the survey was not designed to document military expended materials and these were only the items photographed using still frames. Another extensive remotely operated vehicle survey along the continental shelf break and canyons in the northeast and mid-Atlantic region found marine debris in 81 percent of individual dives, but the items did not include any visible military expended materials (Quattrini et al., 2015). Underwater surveys of bottom areas off the Gulf coast of Florida with a presumably high potential for military expended materials (based on reported obstructions by fishermen) found no items of military origin, suggesting that expended materials may be widely distributed or may become covered by sediments (U.S. Department of the Navy, 2013a). In a deep-sea trawl survey of the northern Gulf of Mexico, items of military origin were found (artillery shells and a missile), but were among the least-frequently encountered types of debris (Wei et al., 2012).

Military Expended Materials - Munitions

Military expended materials that are munitions and associated with training activities include small-, medium-, and large-caliber projectiles, bombs, missiles, rockets, and grenades. Fragments of exploded munitions are also included because they can result in impacts on invertebrates that are similar to those associated with smaller intact munitions. Military expended materials associated with testing activities are the same except that there are no grenades. Navy training and testing activities in the Study Area include firing a variety of weapons and using a variety of non-explosive training and testing rounds, including small-, medium-, and large-caliber projectiles. Large-caliber projectiles are primarily used in the open ocean beyond 20 NM from shore. Direct strike from bombs, missiles, and rockets would result in types of impacts similar to those of projectiles. However, they are larger than most projectiles and are likely to produce a greater number of fragments. Bombs, missiles, and rockets are designed to explode within about 3 ft. of the sea surface, where marine invertebrates larger than zooplankton are relatively infrequent.

Military Expended Materials Other Than Munitions

Military expended materials other than munitions associated with training and testing activities include a large number of items such as aerial countermeasures, targets (surface and aerial), mine shapes, ship hulk, decelerators/parachutes, acoustic countermeasures, sonobuoys, and other materials such as torpedo accessories, concrete slugs, marine markers, bathythermographs, endcaps, and pistons. Some expended materials used during training and testing activities, including some types of torpedoes and targets, non-explosive mine shapes, and bottom-placed instruments, are recovered.

Chaff, which consists of aluminum-coated glass fibers, may be transported great distances by the wind, beyond the areas where they are deployed, before contacting the sea surface. These materials contact the sea surface and bottom with very little kinetic energy, and their low buoyant weight makes them an inconsequential strike and abrasion risk. Therefore, chaff is not considered to be a potential strike and disturbance stressor.

During a sinking exercise, aircraft, ship, and submarine crews deliver munitions on a surface target, which is a clean, deactivated ship that is deliberately sunk using multiple weapon systems. Sinking exercises occur in specific open ocean areas, outside of the coastal range complexes. Habitat-forming invertebrates are likely absent where sinking exercises are planned because the activity occurs in depths greater than the range for shallow-water and many deep-water coral species (approximately 3,000 m) and away from typical locations for hydrothermal vent or cold seep communities (e.g., seamounts) (Cairns, 2007). It is unlikely that deep-sea hard corals would be impacted by a sinking ship hulk or fragments of a hulk due to their lack of occurrence below depths of about 3,000 m (the depth of the aragonite saturation boundary; see Section 3.4.2.1.1, Habitat Use).

Decelerators/parachutes of varying sizes are used during training and testing activities and may be deployed from aircraft or vessels. Similar to other marine debris such as derelict fishing gear, decelerators/parachutes may kill or injure sessile benthic invertebrates due to covering/shading or abrasion. Activities that expend sonobuoy and air-launched torpedo decelerators/parachutes generally occur in relatively deep water away from the shore. Because they are in the air and water column for a time span of minutes, it is improbable that a decelerator/parachute deployed over deep water could travel far enough to affect shallow-water species (e.g., shallow-water corals). Decelerators/parachutes expended over deep offshore areas may impact deep-water invertebrates (particularly sessile species) by disturbance, strikes, burial, smothering, or abrasion. For example, a decelerator/parachute could cover a sponge or deep-water coral and impair feeding.

3.4.3.4.3.1 Impacts from Military Expended Materials Under Alternative 1

Impacts from Military Expended Materials Under Alternative 1 for Training Activities

As indicated in Appendix F (Military Expended Material and Direct Strike Impact Analyses), under Alternative 1, military expended materials would occur throughout the Study Area, although relatively few items would be expended in the HSTT Transit Corridor. The majority of military expended materials would occur within the Southern California Range Complex.

Military expended materials (munitions and items other than munitions) have the potential to impact invertebrates at the water surface and on the bottom throughout the Study Area. As described in detail in Section 3.4.3.4.3 (Impacts from Military Expended Materials), impacts may include injury or mortality due to direct strike or burial, disturbance, and indirect effects such as increased turbidity. The potential for direct strikes of pelagic zooplankton and squid at the surface would be minimized by their decreased occurrence in surface waters during the day when training activities typically occur.

Proportional impact analysis determined that the total bottom area affected by all military expended materials in all training areas would be about 145 acres annually, ranging from less than 1 acre to about 120.5 acres in specific range complexes and substrate types. This represents much less than 1 percent of available bottom habitat in any range complex. In addition to expended items, recovered materials would temporarily disturb approximately 10 acres of bottom habitat in all training areas combined. The substrate types and associated invertebrate assemblages within the potentially disturbed areas are difficult to predict, as discussed in Appendix F (Military Expended Material and Direct Strike Impact Analyses). Activities conducted throughout the Study Area have the potential to impact hard bottom communities as well as invertebrates within all other habitat types. Activities occurring at depths of less than about 3,000 m may impact deep-water corals. Consequences could include damage, injury, or mortality as a result of projectiles, munitions, or other items. Decelerators/parachutes, wires, and cables could also impact benthic communities if they are mobilized by water currents, although it is expected that most such materials would become buried, encrusted, or otherwise immobilized over time and would not continue to impact individual invertebrates or invertebrate assemblages. Impacts would be most pronounced if all the materials expended within the applicable depth range were deposited on areas of hard substrate supporting long-lived, sessile organisms such as deep-water corals, because it may be assumed that many of the benthic invertebrates present in the impact area footprint would be killed, injured, displaced, or disturbed by the expended materials. In addition, some previously undisturbed bottom area would be affected by activities in subsequent years. Conversely, impacts would be less if the materials were deposited on soft bottom areas containing invertebrate communities that recover relatively quickly from disturbance. Although hard substrate potentially supporting deep-water corals and other invertebrate communities is present in at least some areas in water depths less than 3,000 m, a scenario of all expended materials being deposited on such substrate is unrealistic. Deep-water stony corals are relatively rare in the Hawaiian Archipelago region, and most species are solitary. Hard and mixed bottom types, which support the occurrence of deep-water corals other than sea pens, are relatively rare off the U.S. west coast, accounting for about 10 percent of the substrate from the shelf to depths of 3,000 m (Clarke et al., 2015). These habitat types are often associated with seamounts, banks, and canyons (particularly banks in the Channel Islands region). Based on the results of limited investigation, a low percentage of available hard substrate may be inhabited by deep-water corals or other invertebrate species (Harter et al., 2009; U.S. Department of the Navy, 2010). It is expected that most of the bottom type affected would be soft substrate (Appendix F, Military Expended Material and Direct Strike Impact Analyses). Therefore, although it is possible for a portion of expended items to impact hard substrate and associated sensitive invertebrate communities, the number of exposed individuals would not likely affect the overall viability of populations or species. While the potential for overlap between Navy activities and invertebrates is reduced for those species living in rare habitats, if overlap does occur, any potential impacts would be amplified for those invertebrate species or taxa with limited spatial extent. With the exception of abalones and some shallow-water corals, detailed distribution and habitat utilization information sufficient to support species-specific analysis is generally unavailable.

The impact of military expended materials on marine invertebrates is likely to cause injury or mortality to individuals of soft-bodied species that are smaller than the military expended materials. Zooplankton could therefore be impacted by most military expended materials. Impacts on populations would likely be inconsequential because the number of individuals affected would be small relative to known population sizes, the area exposed to the stressor is extremely small relative to the area of both suitable and occupied habitats, the activities are dispersed such that few individuals would likely be exposed to more than one event, and exposures would be localized and would cease when the military expended material becomes part of the bottom (e.g., buried or encrusted with sessile organisms). However, as discussed previously, research has shown that sedentary/sessile invertebrate communities growing on artificial substrate are often different than those found on natural substrates. Activities involving military expended materials are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

Potentially impacted invertebrates include the ESA-listed black abalone and white abalone. Black abalone and white abalone occur in discreet portions of the Southern California Range Complex (Section 3.4.2.2.1, Black Abalone [*Haliotis cracherodii*], and Section 3.4.2.2.2, White Abalone [*Haliotis sorenseni*]). Training activities involving military expended materials within these areas could, therefore, impact ESA-protected abalone by direct strike.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area. For example, the Navy will not conduct gunnery activities within a specified distance of shallow-water coral reefs and precious coral beds. The mitigation will consequently also help avoid potential impacts on invertebrates that inhabit these areas, including several areas inhabited by white abalone and black abalone.

In general, the Navy does not conduct training activities that use military expended material in shallow-water, rocky areas where ESA-listed black abalones and white abalones typically occur. Materials are primarily expended far from shore, in the open ocean. Some military expended materials may be expended in the nearshore waters of San Clemente Island, mine warfare areas such as Tanner Bank and Cortes Bank, and explosive ordnance disposal training areas where they could sink to the bottom and have localized impacts on invertebrates surrounding the island. Military expended materials would generally not be expected to affect black abalone because of the limited amount of items that would be expended in water depths less than 20 ft. It is conceivable for an item expended offshore to drift shoreward and reach water depths associated with black abalone occurrence and designated critical habitat. It would be possible for military expended materials to fall in offshore waters known to support white abalone, such as Cortes and Tanner Banks. These banks appear to be important habitat for white abalones, and a relatively large population occurs at Tanner Bank (Butler et al., 2006). The probability that military expended materials would fall into specific cracks or crevices occupied by white abalones is low. The potential to impact white abalones is further decreased by the low abalone population density and the widely dispersed use of expendable materials. The majority of military expended material in nearshore and offshore waters surrounding Tanner Bank is chaff and flares, which have a small potential for impacts.

Even though impacts on abalone species would be minimized due to avoidance of some seafloor resources, based on the preceding discussion, there is some potential for abalone species to be exposed. Pursuant to the ESA, the use of military expended materials during training activities as described under Alternative 1 may affect ESA-listed abalone species and black abalone critical habitat. The Navy has consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from Military Expended Materials Under Alternative 1 for Testing Activities

As indicated in Appendix F (Military Expended Material and Direct Strike Impact Analyses), under Alternative 1, military expended materials would occur in the Hawaii Range Complex and Southern California Range Complex.

Military expended materials (munitions and items other than munitions) have the potential to impact invertebrates at the water surface and on the bottom throughout the Study Area. As described in detail in Section 3.4.3.4.3 (Impacts from Military Expended Materials), impacts may include injury or mortality due to direct strike or burial, disturbance, and indirect effects such as increased turbidity. The potential for direct strikes of pelagic zooplankton and squid at the surface would be minimized by their decreased occurrence in surface waters during the day.

Proportional impact analysis determined that the total bottom area affected by all military expended materials in all testing areas would be about 40 acres annually. This represents much less than 1 percent of available bottom habitat in any range complex. In addition to expended items, recovered materials would temporarily disturb an additional small amount of bottom habitat (about 10 acres) in all testing areas combined. The substrate types and associated invertebrate assemblages within the disturbed area is difficult to predict, as discussed in Appendix F (Military Expended Material and Direct Strike Impact Analyses). Activities occurring at depths of less than about 3,000 m may impact deep-water corals.

However, activities conducted in relatively deep water throughout the Study Area have the potential to impact hard bottom communities, including deep-water corals, as well as invertebrates within all other habitat types. Consequences could include damage, injury, or mortality as a result of projectiles, munitions, or other items. Decelerators/parachutes, wires, and cables could also impact benthic communities if the items are moved by water currents, although it is expected that most such materials would become buried, encrusted, or otherwise immobilized over time and would not continue to impact individual invertebrates or invertebrate assemblages. Impacts would be most pronounced if all the materials expended within the applicable depth range were deposited on areas of hard substrate supporting long-lived, sessile organisms such as deep-water corals, because it may be assumed that many of the benthic invertebrates present in the affected areas would be killed, injured, displaced, or disturbed by the expended materials. In addition, some previously undisturbed bottom area would be affected by activities in subsequent years. Conversely, impacts would be less if the materials were deposited on soft bottom areas containing invertebrate communities that recover relatively quickly from disturbance. Although hard substrate potentially supporting deep-water corals and other invertebrate communities is present in at least some areas in water depths less than 3,000 m, a scenario of all expended materials being deposited on such substrate is unrealistic. Deep-water stony corals are relatively rare in the Hawaiian Archipelago region, and most species are solitary. Hard and mixed bottom types, which support the occurrence of deep-water corals other than sea pens, are relatively rare off the U.S. west coast, accounting for about 10 percent of the substrate from the shelf to depths of 3,000 m (Clarke et al., 2015). These habitat types are often associated with seamounts, banks, and canyons. Based on the results of limited investigation, a low percentage of this available hard substrate may be inhabited by deep-water corals or other invertebrate species (U.S. Department of the Navy, 2010). It is expected that most of the bottom type affected would be soft substrate (Appendix F, Military Expended Material and Direct Strike Impact Analyses). Therefore, although it is possible for a portion of expended items to impact hard substrate and associated sensitive invertebrate communities, the number of exposed individuals would not likely affect the overall viability of populations or species.

The impact of military expended materials on marine invertebrates is likely to cause injury or mortality to individuals, particularly soft-bodied organisms that are smaller than the military expended materials. Zooplankton could therefore be impacted by most military expended materials. Impacts on populations would likely be inconsequential because the number of individuals affected would be small relative to known population sizes, the area exposed to the stressor is extremely small relative to the area of both suitable and occupied habitats, the activities are dispersed such that few individuals would likely be exposed to more than one event, and exposures would be localized and would cease when the military expended material becomes part of the bottom (e.g., buried or encrusted with sessile organisms). However, as discussed previously, research has shown that sedentary/sessile invertebrate communities growing on artificial substrate are often different than those found on natural substrates. Activities involving military expended materials are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area. For example, the Navy will not conduct certain activities on live hard bottom. The mitigation will consequently also help avoid potential impacts on invertebrates that inhabit these areas, potentially including areas inhabited by white abalone and black abalone.

In general, the Navy does not conduct testing activities that use military expended material in shallow-water, rocky areas where ESA-listed black abalones and white abalones typically occur. Materials are primarily expended far from shore, in the open ocean. Some military expended materials may be expended in the nearshore waters of San Clemente Island and mine warfare areas such as Tanner Bank and Cortes Bank, where they could sink to the bottom and have localized impacts on invertebrates surrounding the island. Military expended materials would generally not be expected to affect the ESA-listed black abalone because of the limited amount of items that would be expended in water depths less than 20 ft. It is conceivable for an item expended offshore to drift shoreward and reach water depths associated with black abalone occurrence and designated critical habitat. It would be possible for military expended materials to fall in offshore waters known to support white abalone, such as Cortes and Tanner Banks. These banks appear to be important habitat for white abalones, and a relatively large population occurs at Tanner Bank (Butler et al., 2006). The probability that military expended materials would fall into specific cracks or crevices occupied by white abalones is low. The potential to impact white abalones is further decreased by the low abalone population density and the widely dispersed use of expendable materials. The majority of military expended material in nearshore and offshore waters surrounding Tanner Bank is chaff and flares, which have a small potential for impacts.

Even though impacts on abalone species will be minimized due to mitigation measures, based on the preceding discussion, there is some potential for abalone species to be exposed. Pursuant to the ESA, the use of military expended materials during testing activities as described under Alternative 1 may affect ESA-listed abalone species and black abalone critical habitat. The Navy has consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.4.3.4.3.2 Impacts from Military Expended Materials Under Alternative 2

Impacts from Military Expended Materials Under Alternative 2 for Training Activities

The locations of training activities using military expendable materials would be the same under Alternatives 1 and 2. The total area affected for all training activities combined would increase by about 15 acres (to 160.5 acres) annually under Alternative 2, and therefore the potential impacts would be similar between the two alternatives. Refer to Section 3.4.3.4.3.1 (Impacts from Military Expended Materials Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.4.3.1 (Impacts from Military Expended Materials Under Alternative 1), the Navy will implement mitigation to avoid impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area. For example, the Navy will not conduct gunnery activities within a specified distance of shallow-water coral reefs and precious coral beds. The mitigation will consequently also help avoid potential impacts on invertebrates that inhabit these areas, including several areas inhabited by white abalone and black abalone.

Even though impacts on abalone species would be minimized due to avoidance of some seafloor resources, there is some potential for abalone species to be exposed. Pursuant to the ESA, the use of military expended materials during training activities as described under Alternative 2 may affect ESA-listed abalone species and black abalone critical habitat.

Impacts from Military Expended Materials Under Alternative 2 for Testing Activities

The locations of testing activities using military expendable materials would be the same under Alternatives 1 and 2. The total area affected for all testing activities combined would increase by about 13 acres (to 51 acres) annually under Alternative 2, and therefore the potential impacts would be similar between the two alternatives. Refer to Section 3.4.3.4.3.1 (Impacts from Military Expended Materials Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.4.3.1 (Impacts from Military Expended Materials Under Alternative 1), the Navy will implement mitigation to avoid impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area. For example, the Navy will not conduct certain activities on live hard bottom. The mitigation will consequently also help avoid potential impacts on invertebrates that inhabit these areas, potentially including areas inhabited by white abalone and black abalone.

Even though impacts on abalone species would be minimized due to avoidance of some seafloor resources, there is some potential for abalone species to be exposed. Pursuant to the ESA, the use of military expended materials during testing activities as described under Alternative 2 may affect ESA-listed abalone species and black abalone critical habitat.

3.4.3.4.3.3 Impacts from Military Expended Materials Under the No Action Alternative

Impacts from Military Expended Materials Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various physical disturbance and strike stressors (e.g., military expended materials) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.4.4 Impacts from Seafloor Devices

For a discussion of the types of activities that use seafloor devices, where they are used, and how many activities would occur under each alternative, see Appendix B (Activity Stressor Matrices). Seafloor devices include items that are placed on, dropped on, or moved along the substrate for a specific purpose, and include mine shapes, anchor blocks, anchors, bottom-placed instruments, bottom-crawling unmanned underwater vehicles, and bottom placed targets that are recovered (not expended). Placement or deployment of seafloor devices would cause disturbance, injury, or mortality to marine invertebrates within the footprint of the device. These items could potentially break hard substrate and associated biogenic habitats (e.g., hard coral skeletons). Objects placed on the bottom may attract invertebrates, or provide temporary attachment points for invertebrates. Some invertebrates attached to the devices would be removed from the water when the devices are recovered. A shallow depression may remain for some time in the soft bottom sediment where an anchor was dropped, potentially altering the suitability of the affected substrate for benthic invertebrates temporarily (possibly months).

Seafloor devices may also disturb marine invertebrates outside the footprint of the device, and would cause temporary (possibly hours to days) local increases in turbidity and sedimentation near the bottom, along with some changes in scouring/deposition patterns in higher current areas with soft bottom. Sedimentation can smother sessile invertebrates, while turbidity may affect respiratory organs or impair the ability of filter-feeding invertebrates to obtain food (e.g., by clogging their feeding structures or diluting the amount of food in the surrounding volume of water). However, the brief episodes of minor turbidity associated with Navy seafloor devices would be localized and the effects do not change the substrate type. Compared to overall populations, relatively few individuals would be affected.

Precision anchoring, and the associated potential impacts, is qualitatively different than other seafloor devices because the activity involves repeated disturbance to the same soft bottom areas. Precision anchoring may result in temporary and localized disturbances to water column and bottom habitats. For example, an anchor may shift due to changing currents or vessel movement and the mooring chain may drag across the bottom, causing abrasion and impacts on benthic species (Davis et al., 2016). Anchor impacts on the bottom would likely crush a small number of benthic invertebrates. Bottom disturbance would result in localized sedimentation and turbidity, which could smother invertebrates or affect respiration or feeding. Turbidity would quickly dissipate (i.e., minutes to hours) following the exercise, and many soft bottom invertebrates are burrowing organisms that would be unaffected by shallow burial. Although precision anchoring occurs in soft-bottom areas, where invertebrate populations are generally resilient to disturbance, invertebrates in designated anchorage areas may be prevented from fully recovering due to long-term use, and benthic composition may be changed compared to historical conditions.

3.4.3.4.4.1 Impacts from Seafloor Devices Under Alternative 1

<u>Impacts from Seafloor Devices Under Alternative 1 for Training Activities</u>

As indicated in Section 3.0.3.3.4.3 (Seafloor Devices), under Alternative 1, seafloor devices would occur in the Hawaii Range Complex and Southern California Range Complex.

Seafloor devices are either stationary or move very slowly along the bottom and pose little threat to highly mobile organisms such as crabs and shrimp, with the exception of individuals that might be struck as an item settles on the bottom. Sessile or less mobile benthic organisms such as sponges, sea snails, and echinoderms would be more likely to be impacted. As discussed above in Section 3.4.3.4.4 (Impacts from Seafloor Devices), impacts may include injury or mortality due to direct strike, disturbance, smothering, and impairment of respiration or filter-feeding due to increased sedimentation and turbidity. Impacts on invertebrates resulting from movement of the devices through the water column before they contact the bottom would likely consist of only temporary displacement as the object passes by.

Although intentional placement of seafloor devices on bottom structure is avoided, activities occurring at depths less than about 3,000 m may inadvertently impact deep-water corals, other invertebrates associated with hard bottom, and other marine invertebrate assemblages. However, most activities involving seafloor devices (e.g., anchors for mine shapes, light salvage targets) are typically conducted in nearshore areas far from deep-sea corals. Most seafloor devices are operated in the nearshore environment on bottom habitats suitable for deployment and retrieval (e.g., soft or intermediate bottom). Consequences of strikes could include damage, injury, or mortality for each device, mooring, or anchor. Hard substrate potentially supporting deep-water corals and other invertebrate communities is present on the continental shelf break and slope. A low percentage of deep substrate on the continental shelf is suitable for hard bottom communities. Based on the results of limited investigation, a low percentage of available hard substrate may be inhabited by deep-water corals or other invertebrate species (Harter et al., 2009; U.S. Department of the Navy, 2010), although the percentage of coverage may be higher in some areas, such as undersea banks associated with the Channel Islands. The number of organisms affected is not expected to result in impacts on the viability of invertebrate populations.

Salvage operations under Alternative 1 would occur three times per year in Puuloa Underwater Range, Naval Defensive Sea Area, Keehi Lagoon, or training areas in Pearl Harbor. The Puuloa Underwater Range and Naval Defensive Sea Area are located at the entrance to Pearl Harbor, and Keehi Lagoon is adjacent to Joint Base Pearl Harbor-Hickam. Salvage training activities that would result in contact with the bottom include removing sunken vessels or aircraft from the seafloor and conducting ocean recovery activities. The infrastructure to keep sunken items in place for these activities was installed in 2009 and would not need to be installed again. Salvage operations typically occur in areas that have been previously disturbed. Potential impacts on marine invertebrates would be limited to the area directly below the vessel, but this area could experience repeated impacts from raising and lowering items during each training activity.

During precision anchoring, impact of the anchor on the bottom would likely crush a relatively small number of benthic invertebrates. Effects associated with turbidity and sedimentation would be temporary and localized. Precision anchoring would occur multiple times per year in the same general location. Therefore, although invertebrates in soft bottom areas are generally resilient to disturbance, community composition may be chronically disturbed at anchoring sites that are used repeatedly. However, the impact is likely to be inconsequential and not detectable at the population level for species occurring in the region near the anchoring locations.

In summary, the impact of seafloor devices on mostly soft bottom invertebrates is likely to cause injury or mortality to some individuals, but impacts on populations would be inconsequential because the area exposed to the stressor is extremely small relative to the area of both suitable and occupied habitats, and the activities are generally dispersed such that few individuals would likely be exposed to more than one event (although seafloor device use is concentrated in some areas such as anchorages and mine ranges). In addition, exposures would be localized and temporary, and the organisms most frequently impacted would be burrowing soft bottom invertebrates that are relatively resilient to localized sediment disturbance. Activities involving seafloor devices are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

The Navy will implement mitigation that includes not conducting precision anchoring (except in designated anchorages) within the anchor swing circle of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks to avoid potential impacts from seafloor devices on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). This mitigation will consequently help avoid potential impacts on invertebrates that inhabit these areas, including several areas inhabited by ESA-listed abalone species.

Potential impacts from seafloor devices on ESA-listed abalone species and abalone habitat would be discountable. Navy practice is to place seafloor devices on soft bottom areas. Furthermore, most black abalone rocky habitat is too shallow to meet training requirements that would use seafloor devices. Some shallow water seafloor devices are used by the Navy along the California coast at Silver Strand but only at designated sandy, soft bottom areas not associated with black abalone habitat. Navy activities would not overlap with designated black abalone critical habitat, and critical habitat has not been designated for white abalone under the ESA. Pursuant to the ESA, the use of seafloor devices during training activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Seafloor Devices Under Alternative 1 for Testing Activities

As indicated in Section 3.0.3.3.4.3 (Seafloor Devices), under Alternative 1, the use of seafloor devices would occur in the Hawaii Range Complex and Southern California Range Complex.

Seafloor devices are either stationary or move very slowly along the bottom and pose little threat to highly mobile organisms such as crabs and shrimp, with the exception of individuals that might be struck as a device settles on the bottom. Sessile or less mobile benthic organisms such as sponges, sea snails, and echinoderms would be more likely to be impacted. As discussed in Section 3.4.3.4.4 (Impacts from Seafloor Devices), impacts may include injury or mortality due to direct strike, disturbance, smothering, and impairment of respiration or filter-feeding due to increased sedimentation and turbidity. Impacts on invertebrates resulting from movement of the devices through the water column before they contact the bottom would likely consist of only temporary displacement as the object passes by.

In testing areas where bottom-crawling unmanned underwater vehicles are used, benthic organisms would be exposed to strike and disturbance in the relatively small area transited by the vehicles. Potential consequences of a strike by bottom-crawling unmanned underwater vehicles would be dependent upon the type of benthic invertebrate encountered. Impacts would consist primarily of disturbance; burrowing invertebrates are unlikely to be injured or killed as a result of pressure exerted by bottom-crawling vehicles. The largest unmanned underwater vehicle weighs 92 lb. out of the water and has a footprint of 4.8 square feet. Assuming, worst case, that the unmanned underwater vehicle's buoyant weight is 92 lb., it exerts a pressure of only 0.133 lb. per square inch. Few benthic marine invertebrates would be injured by this pressure level, particularly over soft sediments which would compress under the invertebrate and relieve some of the pressure being exerted by the crawler.

Although intentional placement of seafloor devices on hard substrate is avoided, activities occurring at depths less than about 3,000 m may inadvertently impact deep-water corals, other invertebrates associated with live hard bottom, and other marine invertebrate assemblages. However, most activities involving seafloor devices (e.g., anchors for mine shapes, bottom crawlers) are typically conducted in the nearshore ocean far from deep-sea corals. Most seafloor devices are operated in the nearshore environment, away from shallow-water corals and on bottom habitats suitable for deployment and retrieval (e.g., soft or intermediate bottom). Consequences of a strike could include damage, injury, or mortality for each device, mooring, or anchor. Hard substrate potentially supporting deep-water corals and other invertebrate communities is present on the continental shelf break and slope. A low percentage of bottom habitat in deep portions of on the continental shelf is suitable for hard bottom communities. Based on the results of limited investigations, a low percentage of available hard substrate may be inhabited by deep-water corals or other invertebrate species (U.S. Department of the Navy, 2010), although the percentage of coverage may be higher in some areas, such as undersea banks associated with the Channel Islands. Individual organisms would not likely be affected directly or indirectly to the extent that the viability of populations or species would be impacted.

The impact of seafloor devices on mostly soft-bottom invertebrates is likely to cause injury or mortality to some individuals, but impacts on populations would be inconsequential because the area exposed to the stressor is extremely small relative to the area of both suitable and occupied habitats, and the activities are generally dispersed such that few individuals would likely be exposed to more than one event (although seafloor device use is concentrated in some areas such as anchorages and mine ranges). In addition, exposures would be localized and temporary, and the organisms most frequently impacted would be burrowing soft-bottom invertebrates that are relatively resilient to localized sediment disturbance. Activities involving seafloor devices are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

Potential impacts from seafloor devices on ESA-listed abalone species and abalone habitat would be discountable. Navy practice is to place seafloor devices on soft bottom areas. Furthermore, most black abalone rocky habitat is too shallow to meet testing requirements that would use seafloor devices. Some shallow water seafloor devices are used by the Navy along the California coast at Silver Strand but only at designated sandy, soft bottom areas not associated with black abalone habitat. Navy activities would not overlap with designated black abalone critical habitat, and critical habitat has not been designated for white abalone under ESA. Pursuant to the ESA, the use of seafloor devices during testing activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.4.4.2 Impacts from Seafloor Devices Under Alternative 2

Impacts from Seafloor Devices Under Alternative 2 for Training Activities

The locations and types of training activities using seafloor devices would be the same under Alternatives 1 and 2. Compared to Alternative 1, there would be a very small decrease in the number of activities involving seafloor devices in the Southern California Range Complex. However, the small decrease would not result in substantive changes to the potential for impacts or the types of impacts on invertebrates. Refer to Section 3.4.3.4.4.1 (Impacts from Seafloor Devices Under Alternative 1) for a discussion of impacts on invertebrates.

The Navy will implement mitigation that includes not conducting precision anchoring (except in designated anchorages) within the anchor swing circle of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks to avoid potential impacts from seafloor devices on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). This mitigation will consequently help avoid potential impacts on invertebrates that inhabit these areas, including several areas inhabited by ESA-listed abalone species.

Seafloor devices could occur within potential ESA-listed abalone species habitat off San Clemente Island but would not be expected to affect abalones because seafloor devices are placed in soft bottom areas. Navy activities would not overlap with designated black abalone critical habitat, and critical habitat has not been designated for white abalone under the ESA. Pursuant to the ESA, the use of seafloor devices during training activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Seafloor Devices Under Alternative 2 for Testing Activities

The locations and types of testing activities using seafloor devices would be the same under Alternatives 1 and 2. There would be a very small increase in the number of testing activities using seafloor devices in the Southern California Range Complex. However, the increase would not result in substantive changes to the potential for impacts or the types of impacts on invertebrates. Refer to Section 3.4.3.4.4.1 (Impacts from Seafloor Devices Under Alternative 1) for a discussion of impacts on invertebrates.

Seafloor devices could be deployed within ESA-listed abalone species potential habitat off San Clemente Island but would not be expected to affect abalones because seafloor devices are generally placed in soft bottom areas. Navy activities would not overlap with designated black abalone critical habitat, and critical habitat has not been designated for white abalone under ESA. Pursuant to the ESA, the use of seafloor devices during testing activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.4.4.3 Impacts from Seafloor Devices Under the No Action Alternative

Impacts from Seafloor Devices Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various physical disturbance and strike stressors (e.g., seafloor devices) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.4.5 Impacts from Pile Driving

In this section, impacts on invertebrates resulting from pile driving and vibratory pile extraction are considered in the context of injury, mortality, or displacement that may occur due to physical strikes and disturbance. Pile driving produces impulsive sound that may also affect invertebrates. Impacts associated with impulsive sound are discussed with other acoustic stressors in Section 3.4.3.1.4 (Impacts from Pile Driving).

Installation and removal of piles could crush or injure invertebrates due to direct physical impact. Direct impacts would be most likely for sessile or slow-moving species such as bivalve molluscs, worms, and echinoderms. Individuals located near the activities but not directly impacted could be disturbed and show behavioral reactions (e.g., fleeing from the area, shell closure, changes in activity). Behavioral reactions require energy expenditure and may result in additional effects such as feeding disruption or increased exposure to predators.

Bottom disturbance resulting from pile installation and removal would result in sediment displacement and turbidity. Suspended sediment particles may affect respiratory organs or impair the ability of filter-feeding invertebrates to obtain food (e.g., by clogging their feeding structures or diluting the amount of food in the surrounding volume of water).

3.4.3.4.5.1 Impacts from Pile Driving Under Alternative 1

Impacts from Pile Driving Under Alternative 1 for Training Activities

Under Alternative 1, two events involving pile driving and removal would occur annually in the nearshore and surf zone at Silver Strand Training Complex or Camp Pendleton, both in the Southern California Range Complex. Each annual event would consist of intermittent disturbance over an estimated 20 days during installation and 10 days during removal. Invertebrates could be exposed to substrate vibration and other disturbance for a total of 90 minutes per 24-hour period during installation, and could be similarly exposed for an estimated total of 72 minutes per 24-hour period during pile removal.

Invertebrates could be crushed, injured, displaced, or react behaviorally as a result of pile installation and removal. In addition, turbidity could affect respiration and feeding in some individuals. However, this activity occurs along high energy beaches where organisms are resilient to frequent sediment disturbance. During the relatively short duration that piles are in the water (less than 2 weeks per event), limited colonization of the piles by fast-growing, sedentary invertebrates would likely occur. For example, the planktonic young of sedentary invertebrates such as mussels, hydroids, bryozoans, sea squirts, abalones, and sponges could use the piles for attachment. Adults of mobile species such as crabs could use the piles for foraging or refuge. Removal of the piles would result in mortality to limited-mobility and attached sessile species, and displacement and possibly injury to more mobile species. Compared to overall population size, only a very small number of individuals would be affected. In addition, pile driving events would occur infrequently (two times per year), and impacts on the sandy substrate would be recoverable. Effects to overall invertebrate populations would not be discernable.

Pile driving activities would not be conducted in areas that could support ESA-listed abalone species, and would not occur in black abalone critical habitat. Critical habitat for white abalone is not designated under the ESA. Pursuant to the ESA, pile driving and removal during training activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Pile Driving Under Alternative 1 for Testing Activities

There would be no pile driving or vibratory pile extraction associated with testing activities. Therefore, pile driving is not analyzed in this subsection.

3.4.3.4.5.2 Impacts from Pile Driving Under Alternative 2

Impacts from Pile Driving Under Alternative 2 for Training Activities

The locations, number of training events, and potential effects associated with pile driving and vibratory pile extraction would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.4.5.1 (Impacts from Pile Driving Under Alternative 1) for a discussion of impacts on invertebrates.

Pile driving activities would not be conducted in areas that could support ESA-listed abalone species, and would not occur in black abalone critical habitat. Critical habitat for white abalone is not designated under the ESA. Pursuant to the ESA, the pile driving and removal during training activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Pile Driving Under Alternative 2 for Testing Activities

There would be no pile driving or vibratory pile extraction associated with testing activities. Therefore, pile driving is not analyzed in this subsection.

3.4.3.4.5.3 Impacts from Pile Driving Under the No Action Alternative

Impacts from Pile Driving Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training activities in the HSTT Study Area. Various physical disturbance and strike stressors (e.g., pile driving) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.5 Entanglement Stressors

This section analyzes the potential entanglement impacts of the various types of expended materials used by the Navy during training and testing activities within the Study Area. Included are potential impacts from wires and cables, decelerators/parachutes, and biodegradable polymer. Aspects of entanglement stressors that are applicable to marine organisms in general are presented in Section 3.0.3.6.4 (Conceptual Framework for Assessing Effects from Entanglement). In this section, only potential impacts of these items as entanglement stressors are discussed. Abrasion and covering/shading impacts on sessile benthic invertebrates are discussed with physical impacts in Section 3.4.3.4.3 (Impacts from Military Expended Materials).

Marine invertebrates are likely less susceptible than vertebrates to entanglement, as illustrated by the fact that fishing nets which are designed to take pelagic marine invertebrates operate by enclosing or entrapping rather than entangling (Chuenpagdee et al., 2003). However, entanglement may be possible for some species and some expended items. A survey of marine debris entanglements found that marine invertebrates accounted for 16 percent of all animal entanglements (Ocean Conservancy, 2010). The same survey cites potential entanglement in military items only in the context of waste-handling aboard ships, and not for military expended materials. A summary of the effects of litter on various marine species identified potential impacts on some invertebrate taxa, particularly mobile benthic species such as crabs and sea stars, that may become entangled in debris (e.g., nets) after attempting to move through the items (National Oceanic and Atmospheric Administration Marine Debris Program, 2014b). The potential for a marine invertebrate to become entangled in wires, cables, decelerators/parachutes, or biodegradable polymer is considered remote. The materials generally do not have the characteristics required to entangle marine species. Wires and cables are essentially rigid lines. Sonobuoy components may include plastic mesh and a float unit. Although mesh items have increased potential for entangling marine animals in general, and invertebrates can become entangled in nets (Ocean Conservancy, 2010), invertebrates are not particularly susceptible to entanglement in these items. Decelerators/parachutes have large openings between the cords separating the decelerator/parachute fabric from the release mechanism. There is no plausible scenario in which decelerator/parachute cords would tighten around and hold a mobile invertebrate. Decelerators/parachutes sink slowly through the water column, although many have weights attached to their lines to speed their sinking. Invertebrates in the water column with limited mobility (e.g., jellyfish, zooplankton) could be trapped in decelerator/parachute fabric as it sinks. The potential effects of decelerators/parachutes covering sessile invertebrate species on the bottom is discussed in Section 3.4.3.4.3 (Impacts from Military Expended Materials). Based on the constituents of the biodegradable polymer the Navy proposes to use, it is anticipated that the material would break down into small pieces within a few days to weeks and break down further and dissolve into the water column within weeks to a few months.

3.4.3.5.1 Impacts from Wires and Cables

Fiber-optic cables, torpedo guidance wires, sonobuoy wires, and expendable bathythermograph wires would be expended during training and testing activities. For a discussion of the types of activities that use wires and cables, see Appendix B (Activity Stressor Matrices).

A marine invertebrate could become temporarily entangled and escape unharmed, it could be held tightly enough that it could be injured during its struggle to escape, it could be preyed upon while entangled, or it could starve while entangled. The probability of these outcomes cannot be predicted because interactions between invertebrate species and entanglement hazards are not well known. However, it is unlikely that an invertebrate would become entangled in wires or cables. The items would be essentially linear after deployment, as they sink through the water column. Once the items reach the bottom, they could be moved into different shapes or loop around objects due to water currents, but the items are not expected to form tight coils, and the possibility of an invertebrate being ensnared is remote. Fiber-optic cables are relatively brittle and readily break if knotted, kinked, abraded against sharp objects, or looped beyond the items' bend radius of 3.4 millimeters. The wires and cables would eventually become buried in sediment or encrusted by marine growth, which would eliminate or further reduce the entanglement potential. The small number of items expended across the Study Area results in an extremely low rate of potential encounter for marine invertebrates.

3.4.3.5.1.1 Impacts from Wires and Cables Under Alternative 1

Impacts from Wires and Cables Under Alternative 1 for Training Activities

Under Alternative 1, fiber-optic cables, guidance wires, sonobuoy wires, and bathythermograph wires would be expended during sinking exercises, anti-submarine warfare activities, torpedo exercises, and various mine warfare and countermeasures exercises in the Hawaii Range Complex, Southern California Range Complex, and Transit Corridor. Compared to sonobuoy wires, a low number of fiber-optic cables, guidance wires, and bathythermograph wires are expended in the Study Area. The majority of expended items would be sonobuoy wires, and most of the sonobuoy wires would be expended in the Southern California Range Complex. The number of wires and cables expended in other areas is substantially lower.

All locations of wire and cable use potentially coincide with deep-water corals and other invertebrates associated with live hard bottom areas in water depths less than 3,000 m. The portion of suitable substrate occupied by living coral is generally low, and coincidence with such low densities of linear materials is unlikely. However, in some areas, such as undersea banks associated with the Channel Islands offshore of southern California, deep-water corals may cover a greater portion of available hard habitat (refer to Section 3.4.2.3.3, Corals, Hydroids, Jellyfish [Phylum Cnidaria]).

The impact of wires and cables on marine invertebrates is not likely to cause injury or mortality to individuals because of the linear and somewhat rigid nature of the material. Impacts on individuals and populations would be inconsequential because the area exposed to the stressor is extremely small relative to the distribution ranges of most marine invertebrates, the activities are dispersed such that few individuals would likely be exposed to more than one event, and exposures would be localized. In addition, marine invertebrates are not particularly susceptible to entanglement stressors, as most would avoid entanglement and simply be temporarily disturbed. Activities involving wires and cables are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at individual or population levels.

ESA-listed abalone species do not occur in offshore areas where torpedo launches would occur and would not be exposed to guidance wires. Airborne mine neutralization activities and fiber-optic cables expended during training activities could occur in nearshore areas of the Southern California Range Complex, where the ESA-listed abalone species are present. However, abalone species would not be entangled by fiber-optic cables or sonobuoy wires because they are sedentary invertebrates. There is no probable scenario in which an abalone would be ensnared by a fiber-optic cable on the bottom and suffer adverse effects. Wires and cables would not affect essential biological features of black abalone critical habitat, which consist of adequate substrate, food availability, and water quality and circulation patterns. Critical habitat has not been designated for white abalone under the ESA. Pursuant to the ESA, the use of wires and cables during training activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Wires and Cables Under Alternative 1 for Testing Activities

Under Alternative 1, testing activities that expend fiber-optic cables, guidance wires, and sonobuoy wires, and bathythermograph wires would occur in the Hawaii Range Complex and Southern California Range Complex. Wires and cables would not be expended within the HSTT Transit Corridor during testing activities. The majority of expended items would be sonobuoy wires. Sonobuoy wires would be expended in both range complexes but would be concentrated in the Southern California Range Complex.

All locations of fiber-optic cable, guidance wire, and sonobuoy wire use potentially coincide with deep-water corals and other invertebrates associated with live hard bottom areas in water depths less than 3,000 m. However, the portion of suitable substrate occupied by living coral is very low and coincidence with such low densities of linear materials is unlikely.

The impact of wires and cables on marine invertebrates is not likely to cause injury or mortality to individuals because of the linear and somewhat rigid nature of the material. Impacts on individuals and populations would be inconsequential because the area exposed to the stressor is extremely small relative to the distribution ranges of most marine invertebrates, the activities are dispersed such that few individuals would likely be exposed to more than one event, and exposures would be localized. In addition, marine invertebrates are not particularly susceptible to entanglement stressors, as most would avoid entanglement and simply be temporarily disturbed. Activities involving wires and cables are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at individual or population levels.

ESA-listed abalone species do not occur in areas offshore where torpedo launches would occur and would not be exposed to and guidance wires. Airborne mine neutralization activities and fiber-optic cables expended during testing activities could occur in the nearshore areas of Southern California Range Complex, where the ESA-listed abalone species are present. However, as discussed above for impacts due to training activities, abalone species would not be entangled by fiber-optic cables. Wires and cables would not affect essential biological features of black abalone critical habitat, which consist of adequate substrate, food availability, and water quality and circulation patterns. Critical habitat has not been designated for white abalone under the ESA. Pursuant to the ESA, the use of wires and cables during testing activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.5.1.2 Impacts from Wires and Cables Under Alternative 2

Impacts from Wires and Cables Under Alternative 2 for Training Activities

Under Alternative 2, the locations and types of potentially entangling expended items used would be the same as under Alternative 1. There would be a small increase in the number of sonobuoy wires expended in the Southern California Range Complex. The overall result would be an increase of about 2 percent in the total number of items expended. The difference is not expected to result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.5.1.1 (Impacts from Wires and Cables Under Alternative 1) for a discussion of potential entanglement impacts resulting from wires and cables associated with training activities.

As discussed in Section 3.4.3.5.1.1 (Impacts from Wires and Cables Under Alternative 1), pursuant to the ESA, the use of wires and cables during training activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

Impacts from Wires and Cables Under Alternative 2 for Testing Activities

Under Alternative 2, the locations and type of potentially entangling expended items used would be the same as under Alternative 1. There would be a small increase in the number of fiber-optic cables expended in the Southern California Range Complex and sonobuoy wires expended in both range complexes. The additional items would represent an overall increase of less than 3 percent of the total amount of materials expended. The difference is not expected to result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.5.1.1 (Impacts from Wires and

Cables Under Alternative 1) for a discussion of potential entanglement impacts resulting from wires and cables associated with testing activities.

As discussed in Section 3.4.3.5.1.1 (Impacts from Wires and Cables Under Alternative 1), pursuant to the ESA, the use of wires and cables during testing activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.5.1.3 Impacts from Wires and Cables Under the No Action Alternative

Impacts from Wires and Cables Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various entanglement stressors (e.g., wires and cables) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.5.2 Impacts from Decelerators/Parachutes

Decelerators/parachutes of varying sizes are used during training and testing activities. For a discussion of the types of activities that use decelerators/parachutes and the physical characteristics of these expended materials, see Section 3.0.3.3.5.2 (Decelerators/Parachutes). Aircraft-launched sonobuoys, lightweight torpedoes, submarine warfare training targets, aerial targets, and other devices deployed from aircraft or vessels use decelerators/parachutes that are made of nylon or a combination of cloth and nylon. Small and medium decelerators/parachutes have weights attached to the lines for rapid sinking, but large and extra-large decelerators/parachutes do not. At water impact, the decelerator/parachute assembly is expended, and it sinks away from the unit. Small and medium decelerator/parachute assemblies may remain at the surface for 5 to 15 seconds before the decelerator/parachute and its housing sink to the bottom, where it becomes flattened. Large and extra-large decelerators/parachutes may remain at the surface or suspended in the water column for a longer time due to the lack of weights but eventually also sink to the bottom and become flattened. Because they are in the air and water column for a time span of minutes, it is unlikely that a small or medium decelerator/parachute deployed in areas greater than 3 NM from the shore could travel far enough to affect invertebrates located in shallow nearshore areas. Larger decelerators/parachutes could move a greater distance due to their slower sinking time. Movement of the decelerator/parachute in the water or along the bottom may break more fragile invertebrates such as deep-water corals which would also reduce suitable hard substrate for encrusting invertebrates. Deep-water coral species potentially occur everywhere that decelerator/parachute use occurs. Corals (shallow-water and deep-water) are susceptible to entanglement in decelerators/parachutes, but the principal mechanisms of damage are shading, abrasion, and breakage (refer to Section 3.4.3.4.3 [Impacts from Military Expended Materials] for a discussion of these impacts). On large enough spatial and temporal scales, these impacts could affect a sufficient number of individuals to reduce the extent of coral coverage. However, available studies suggest a very low percentage of suitable habitat is occupied by deep sea corals, making coincidence with entangling decelerators/parachutes very unlikely. Refer to Section 3.4.2.3.3 (Corals, Hydroids, Jellyfish [Phylum Cnidaria]) for details on the study results. In addition to corals, other sessile benthic invertebrates such as sponges, anemones, and hydrozoans could be affected by damage, burial, smothering, or abrasion.

A decelerator/parachute or attached lines sinking through the water column is unlikely to affect pelagic invertebrates. The lines would result in only temporary displacement of individuals. Most pelagic invertebrates would be too small to be ensnared, and the lines would be relatively straight as the decelerator/parachute descends, making entanglement of larger invertebrates such as jellyfish or squid highly unlikely. In addition, there are large openings between the cords. The decelerator/parachute mesh is solid, permitting only microscopic animals to pass through it. Some individuals of relatively slow-moving species (e.g., jellyfish, swimming crabs) could therefore be caught in a billowed decelerator/parachute as it sinks. However, although some are weighted, decelerators/parachutes sink relatively slowly through the water column (potential time span of minutes), and would likely impact few individuals larger than zooplankton. Any individuals trapped within the decelerator/parachute as it sinks may escape, or may remain enclosed for some time and experience potential effects similar to those described for cables and wires (e.g., injury, predation, starvation).

3.4.3.5.2.1 Impacts from Decelerators/Parachutes Under Alternative 1

Impacts from Decelerators/Parachutes Under Alternative 1 for Training Activities

Under Alternative 1, activities involving decelerator/parachute use would occur in the Hawaii Range Complex, Southern California Range Complex, and the HSTT Transit Corridor. The majority of expended items would be small decelerators/parachutes; only a small number of medium, large, and extra-large decelerators/parachutes would be used. Small and medium decelerators/parachutes are typically used with aircraft-launched sonobuoys and lightweight torpedoes, while large decelerators/parachutes are associated with items such as illumination flares and targets (Section 3.0.3.3.5.2, Decelerators/Parachutes). Large and extra-large decelerators/parachutes would be expended in approximately equal quantities in the Hawaii Range Complex and Southern California Range Complex.

Decelerator/parachute lines could temporarily displace invertebrates in the water column but would be unlikely to ensnare individuals. Decelerator/parachute mesh could envelop invertebrates as the item sinks through the water column. Envelopment would primarily be associated with zooplankton, although other relatively slow-moving invertebrates such as jellyfish and swimming crabs could be caught in a billowed decelerator/parachute. Ensnared individuals may be injured or killed, or may eventually escape. Decelerators/parachutes on the bottom could cover benthic invertebrates, but some would likely be able to move away from the item. It is highly unlikely that an individual invertebrate would be ensnared by a decelerator/parachute on the bottom and suffer adverse effects. Decelerators/parachutes could break or abrade deep-water corals. These impacts are discussed in Section 3.4.3.4.3 (Impacts from Military Expended Materials) in the context of physical disturbance and strike.

The vast majority of marine invertebrates would not encounter a decelerator/parachute. The impact of decelerators/parachutes on marine invertebrates is not likely to cause injury or mortality to individuals, and impacts would be inconsequential because the area exposed to the stressor is extremely small relative to most marine invertebrates' ranges, the activities are dispersed such that few individuals would likely be exposed to more than one event, and exposures would be localized. The surface area of decelerators/parachutes expended across the Study Area is extremely small compared to the relatively low percentage of suitable substrate inhabited by deep-sea coral species, resulting in a low risk of coincidence. In addition, marine invertebrates are not particularly susceptible to entanglement stressors, as most would avoid entanglement and simply be temporarily disturbed. The number of individuals affected would be inconsequential compared to overall invertebrate population numbers. Activities involving decelerators/parachutes are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at individual or population levels.

Decelerators/parachutes are unlikely to drift into most areas where ESA-listed black abalone and white abalone are present due to the typical offshore locations of use (water depths of 600 ft. or more). Potential exceptions include offshore areas known to support these species (e.g., Tanner and Cortes Banks). It is not likely that a sedentary abalone could be ensnared by a decelerator/parachute cord. Impacts would more likely be associated with covering or abrasion. An abalone that becomes covered by a decelerator/parachute could have reduced access to drifting or attached macroalgae until the animal moves away from the item. Respiration could also be affected if an abalone becomes covered by a decelerator/parachute to the extent that water flow is restricted. Potential impacts due to abrasion are discussed in the context of physical disturbance and strikes in Section 3.4.3.4.3 (Impacts from Military Expended Materials). There is a remote possibility that abalone larvae could be caught in a decelerator/parachute as it sinks, although microscopic organisms may be able to pass through the mesh.

Pursuant to the ESA, the use of decelerators/parachutes during training activities as described under Alternative 1 would not affect essential biological features of black abalone critical habitat, and critical habitat has not been designated for white abalone under the ESA. Therefore, the use of decelerators/parachutes would have no effect on designated black abalone critical habitat. Decelerators/parachutes may affect ESA-listed abalone species. The Navy has consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from Decelerators/ Parachutes Under Alternative 1 for Testing Activities

Under Alternative 1, activities involving small decelerators/parachutes would occur in the Hawaii Range Complex and Southern California Range Complex. There would be no medium, large, or extra-large decelerators/parachutes expended during any testing activities. Approximately 60 percent of the small decelerators/parachutes would be expended in the Southern California Range Complex.

Decelerator/parachute lines could temporarily displace invertebrates in the water column but would be unlikely to ensnare individuals. Decelerator/parachute mesh could envelop invertebrates as the item sinks through the water column. Envelopment would primarily be associated with zooplankton, although other relatively slow-moving invertebrates such as jellyfish and swimming crabs could be caught in a billowed decelerator/parachute. Ensnared individuals may be injured or killed, or may eventually escape. Decelerators/parachutes on the bottom could cover benthic invertebrates, but some would likely be able to move away from the item. It is highly unlikely that an individual invertebrate would be ensnared by a decelerator/parachute on the bottom and suffer adverse effects. Decelerators/parachutes could break or abrade deep-water corals. These impacts are discussed in Section 3.4.3.4.3 (Impacts from Military Expended Materials) in the context of physical disturbance and strike.

The vast majority of marine invertebrates would not encounter a decelerator/parachute. The impact of decelerators/parachutes on marine invertebrates is not likely to cause injury or mortality to individuals, and impacts would be inconsequential because the area exposed to the stressor is extremely small relative to the distribution ranges of most marine invertebrates, the activities are dispersed such that few individuals would likely be exposed to more than one event, and exposures would be localized. The surface area of decelerators/parachutes expended across the Study Area is extremely small compared to the relatively low percentage of suitable substrate inhabited by deep-sea coral species, resulting in a low risk of coincidence. In addition, marine invertebrates are not particularly susceptible to entanglement stressors, as most would avoid entanglement and simply be temporarily disturbed. The number of individuals affected would be inconsequential compared to overall invertebrate population numbers. Activities involving decelerators/parachutes are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at individual or population levels.

Decelerators/parachutes would be unlikely to drift into most areas where ESA-listed abalone species are present due to the typical offshore locations of use (water depths of 600 ft. or more). Potential exceptions include offshore areas known to support these species (e.g., Tanner and Cortes Banks). It is not likely that a sedentary abalone could be ensnared by a decelerator/parachute cord. As discussed above for training activities, impacts would more likely be associated with covering or abrasion. Abrasion impacts are discussed in the context of physical disturbance and strikes in Section 3.4.3.4.3 (Impacts from Military Expended Materials).

Pursuant to the ESA, the use of decelerators/parachutes during testing activities as described under Alternative 1 would not affect essential biological features of black abalone critical habitat, and critical habitat has not been designated for white abalone under the ESA. Therefore, the use of decelerators/parachutes would have no effect on designated black abalone critical habitat. Decelerators/parachutes may affect ESA-listed abalone species. The Navy has consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.4.3.5.2.2 Impacts from Decelerators/Parachutes Under Alternative 2

Impacts from Decelerators/Parachutes Under Alternative 2 for Training Activities

Under Alternative 2, the locations of activities using decelerators/parachutes would be the same as Alternative 1. Under Alternative 2, there would be a small increase in the number of small decelerators/parachutes used. An additional 812 small decelerators/parachutes would be expended in the Southern California Range Complex. The difference represents an increase of about 2 percent and would not be expected to result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.5.2.1 (Impacts from Decelerators/Parachutes Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.5.2.1 (Impacts from Decelerators/Parachutes Under Alternative 1), pursuant to the ESA, the use of decelerators/parachutes during training activities as described under Alternative 2 would have no effect on designated black abalone critical habitat, but may affect ESA-listed abalone species.

Impacts from Decelerators/Parachutes Under Alternative 2 for Testing Activities

Under Alternative 2, the locations of activities using decelerators/parachutes would be the same as Alternative 1. Under Alternative 2, there would be a small increase in the number of small decelerators/parachutes used. A total of an additional 760 small decelerators/parachutes would be expended in the Study Area (310 in the Hawaii Range Complex and 450 in the Southern California Range Complex). The difference represents an increase of about 2 percent and would not be expected to result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.5.2.1 (Impacts from Decelerators/Parachutes Under Alternative 1) for a discussion of potential entanglement impacts resulting from decelerators/parachutes associated with testing activities.

As discussed in Section 3.4.3.5.2.1 (Impacts from Decelerators/Parachutes Under Alternative 1), pursuant to the ESA, the use of decelerators/parachutes during testing activities as described under Alternative 2 would have no effect on designated black abalone critical habitat, but may affect ESA-listed abalone species.

3.4.3.5.2.3 Impacts from Decelerators/Parachutes Under the No Action Alternative

Impacts from Decelerators/Parachutes Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various entanglement stressors (e.g., decelerators/parachutes) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.5.3 Impacts from Biodegradable Polymer

Biodegradable polymer is an expended item that is designed to temporarily interact with the propeller(s) of target craft. For a discussion of the types of activities that use vessel entanglement systems and the physical characteristics of these expended materials, see Section 3.0.3.3.5.3 (Biodegradable Polymer). The material would degrade into small pieces within a few days to weeks, after which time the entanglement potential would cease. Impacts on pelagic invertebrates would most likely be limited to temporary displacement as the biodegradable polymer material floats past an animal. Although it is unlikely that most invertebrates would become entangled in the biodegradable polymer material, entanglement is conceivable for relatively large invertebrates that occur in the water column (e.g., jellyfish and squid). Entanglement impacts on benthic species are not expected due to the relatively rapid degradation of the items.

3.4.3.5.3.1 Impacts from Biodegradable Polymer Under Alternative 1

Impacts from Biodegradable Polymer Under Alternative 1 for Training Activities

There would be no use of biodegradable polymer associated with training activities. Therefore, biodegradable polymer is not analyzed in this subsection.

Impacts from Biodegradable Polymer Under Alternative 1 for Testing Activities

Under Alternative 1, a small number of testing activities would involve the use of biodegradable polymer in the Hawaii Range Complex and Southern California Range Complex. It is conceivable that relatively large pelagic invertebrates such as jellyfish would be temporarily entangled, although the probability is low due to the polymer design. The most likely effect would be temporary displacement as the material floats past an animal. Impacts on benthic species would not be expected. Activities involving biodegradable polymer would not yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at individual or population levels.

Impacts on ESA-listed abalone species would not be expected. The polymer material would be expected to remain buoyant until substantial degradation occurs and would have little potential for entanglement of abalones. Critical habitat has not been designated for white abalone under the ESA, and biodegradable polymer would not affect essential features of black abalone critical habitat. Pursuant to the ESA, the use of biodegradable polymer during testing activities as described under Alternative 1 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.5.3.2 Impacts from Biodegradable Polymer Under Alternative 2

Impacts from Biodegradable Polymer Under Alternative 2 for Training Activities

There would be no use of biodegradable polymer associated with training activities. Therefore, biodegradable polymer is not analyzed in this subsection.

Impacts from Biodegradable Polymer Under Alternative 2 for Testing Activities

The locations, number of events, and potential effects associated with biodegradable polymer use would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.5.3.1 (Impacts from Biodegradable Polymer Under Alternative 1) for a discussion of the potential impacts of biodegradable polymer on invertebrates.

Pursuant to the ESA, the use of biodegradable polymer during testing activities as described under Alternative 2 would have no effect on ESA-listed abalone species or critical habitat.

3.4.3.5.3.3 Impacts from Biodegradable Polymer Under the No Action Alternative

Impacts from Biodegradable Polymer Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed testing activities in the HSTT Study Area. Biodegradable polymer is not a part of ongoing Navy activities in the Study Area and this entanglement stressor would not be introduced into the marine environment under the No Action Alternative. Therefore, no change in baseline conditions of the existing environment would occur.

3.4.3.6 Ingestion Stressors

This section analyzes the potential ingestion impacts of the various types of military expended materials used by the Navy during training and testing activities within the Study Area, which may be broadly categorized as munitions and materials other than munitions. Aspects of ingestion stressors that are applicable to marine organisms in general are presented in Section 3.0.3.6.5 (Conceptual Framework for Assessing Effects from Ingestion). The Navy expends the following types of materials that could become ingestion stressors during training and testing in the Study Area: non-explosive practice munitions (small- and medium-caliber), fragments from high-explosives, fragments from targets, chaff and flares, chaff and flare accessories (including end caps, compression pads or pistons, and o-rings), and small decelerators/parachutes. Very few invertebrates are large enough to ingest intact small- and medium-caliber munitions and casings; potential impact resulting from these items would be limited to a few taxa such as squid and octopus. Other military expended materials such as targets, large-caliber projectiles, intact training and testing bombs, guidance wires, sonobuoy tubes, and marine markers are too large for any marine invertebrate to consume and are eliminated from further discussion.

Expended materials could be ingested by marine invertebrates in all large marine ecosystems and open ocean areas. Ingestion could occur at the surface, in the water column, or at the bottom, depending on the size and buoyancy of the expended object and the feeding behavior of the animal. Floating material is more likely to be eaten by animals that may feed at or near the water surface (e.g., jellyfish, squid), while materials that sink to the bottom present a higher risk to both filter-feeding sessile (e.g., sponges) and bottom-feeding animals (e.g., crabs). Most military expended materials and fragments of military expended materials are too large to be ingested by marine invertebrates, and relatively large predatory or scavenging individuals are unlikely to consume an item that does not visually or chemically resemble food (Koehl et al., 2001; Polese et al., 2015). Many arthropods such as blue crab (*Callinectes sapidus*) and spiny lobster are known to discriminate between palatable and unpalatable food items inside the mouth, so in a strict sense, only items that are passed into the interior digestive tract should be considered to be ingested (Aggio et al., 2012). If expended material is ingested by marine invertebrates, the primary risk is blockage in the digestive tract. Most military expended materials are relatively inert in the marine environment, and are not likely to cause injury or mortality via chemical effects (see Section 3.4.3.7, Secondary Stressors, for more information on the chemical properties of these materials). However, pollutants (e.g., heavy metals and polychlorinated biphenyls) may accumulate on the plastic components of some military expended materials. Plastic debris pieces collected at various locations in the North Pacific Ocean had polycyclic aromatic hydrocarbons and pesticides associated with them (Rios et al., 2007). Relatively large plastic pieces could be ingested by some species. However, filter- or deposit-feeding invertebrates have the greatest potential to ingest small plastic items, and any associated pollutants could harm the individual animal or subsequently be incorporated into the food chain.

The potential for marine invertebrates to encounter fragments of ingestible size increases as the military expended materials degrade into smaller fragments over months to decades. Intact munitions, fragments of munitions, and other items could degrade into metal and plastic pieces small enough to be consumed by indiscriminate feeders, such as some marine worms. Deposit-feeding, detritus-feeding, and filter-feeding invertebrates such as amphipods, polychaete worms, zooplankton, and mussels have been found to consume microscale plastic particles (microplastics) that result from the breakdown of larger plastic items (National Oceanic and Atmospheric Administration Marine Debris Program, 2014a; Wright et al., 2013). Ingestion by these types of organisms is the most likely pathway for degraded military expended materials to enter the marine food web. Transfer of microplastic particles to higher trophic levels was demonstrated in one experiment (Setala et al., 2014). Ingestion of microplastics may result in physical effects such as internal abrasion and gut blockage, toxicity due to leaching of chemicals, and exposure to attached pollutants. Potentially harmful bacteria may also grow on microplastic particles (Kirstein et al., 2016). In addition, consumption of microplastics may result in decreased consumption of natural foods such as algae (Cole et al., 2013). Microplastic ingestion by marine worms was shown in one study to result in lower energy reserves (Wright et al., 2013). Microplastic ingestion has been documented in numerous marine invertebrates (e.g., mussels, worms, mysid shrimp, bivalve molluscs, zooplankton, and scleractinian corals (Cole et al., 2013; Hall et al., 2015; Setala et al., 2016; Wright et al., 2013). In an experiment involving pelagic and benthic marine invertebrates with different feeding methods, all species exposed to microplastic particles ingested some of the items (Setala et al., 2016). Deposit-feeding worms and an amphipod species ingested the fewest particles, while bivalves and free-swimming crustaceans ingested higher amounts. Ingestion of plastic particles may result in negative physical and chemical effects to invertebrates, although invertebrates are generally able to discharge these particles from the body. Overall population-level effects across a broad range of species are currently uncertain (Kaposi et al., 2014; Wright et al., 2013).

Biodegradable polymer materials used during marine vessel stopping activities degrade relatively quickly as a result of microbial actions or enzymes. The material breaks down into small pieces within days to weeks, and degrades into particles small enough to dissolve in the water within weeks to months. Molecules formed during degradation can range from complex to simple products, depending on whether the polymers are natural or synthetic (Karlsson & Albertsson, 1998). Items of ingestible size would therefore be produced throughout the breakdown process. However, the products are considered environmentally benign and would be dispersed quickly to undetectable concentrations.

The most abundant military expended material of ingestible size is chaff. The materials in chaff are generally nontoxic in the marine environment except in quantities substantially larger than those any marine invertebrate would likely encounter as a result of Navy training and testing activities. Chaff fibers are composed of an aluminum alloy coating on glass fibers of silicon dioxide (Section 3.0.3.3.6.3, Military Expended Materials Other Than Munitions). Chaff is similar in form to fine human hair, and is somewhat analogous to the spicules of sponges or the siliceous cases of diatoms (U.S. Department of the Navy, 1999). Many invertebrates ingest sponges, including the spicules, without suffering harm (U.S. Department of the Navy, 1999). Marine invertebrates may occasionally encounter chaff fibers in the marine environment and may incidentally ingest chaff when they ingest prey or water. Literature reviews and controlled experiments suggest that chaff poses little environmental risk to marine organisms at concentrations that could reasonably occur from military training and testing (Arfsten et al., 2002; U.S. Department of the Navy, 1999). Studies were conducted to determine the effects of chaff ingestion on various estuarine invertebrates occurring near a site of frequent chaff testing in Chesapeake Bay (Schiff, 1977). American oysters (various life stages), blue crabs (*Callinectes sapidus*), blue mussels (*Mytilus edulis*), and the polychaete worm *Nereis succinea* were force fed a chaff-and-food mixture daily for a few weeks at concentrations 10 to 100 times the predicted exposure level in the Bay. Although some mortality occurred in embryonic oyster larvae from 0 to 48 hours, the authors suggest confounding factors other than chaff (e.g., contaminated experimental water) as the cause. The authors reported no statistically significant mortality or effects on growth rate for any species. Because many invertebrates (e.g., crabs, shrimp) actively distinguish between food and non-food particles, the experimental design represents an unrealistic scenario with respect to the amount of chaff consumed. An investigation of sediments in portions of Chesapeake Bay exposed to aluminized chaff release for approximately 25 years found no significant increase in concentration compared to samples collected 3.7 km from the release area (Wilson et al., 2002).

As described in Section 3.4.2 (Affected Environment), many thousands of marine invertebrate species inhabit the Study Area. Most available literature regarding the effects of debris ingestion on marine invertebrates pertains to microplastics (Goldstein & Goodwin, 2013; National Oceanic and Atmospheric Administration Marine Debris Program, 2014a; Wright et al., 2013). Discussion of potential consumption of larger items is typically focused on fishes, reptiles, mammals, and birds. Consequently, it is not possible to speculate in detail on which invertebrates in which locations might ingest all types of military expended materials. Despite the potential impacts, it is reasonable to conclude that relatively large military expended materials would not be intentionally consumed by actively foraging invertebrates unless they are attracted by other cues (e.g., visual cues such as flashing metal bits that squid might attack). Passively-feeding invertebrates (e.g., shellfish, jellyfish) may accidently ingest small particles by filtration or incidental adhesion to sticky mucus. The potential for impacts on invertebrates from ingestion of military expended materials is also related to the locations of Navy training and testing activities relative to invertebrate population densities. Increased invertebrate densities are associated with the highest densities of microscopic plant food, which are typically located in nearshore waters in closer proximity to nutrient sources or in areas where upwelling tends to occur. Conversely, activities that generate military expended materials occur mostly seaward of nearshore water. Small deposit-feeding, detritus-feeding, and filter-feeding invertebrates would be most likely to ingest small items such as degraded plastic particles, although lobsters reportedly may also ingest microplastics (National Oceanic and Atmospheric Administration Marine Debris Program, 2014a). Though ingestion is possible in some circumstances, due to the overall size and composition of military expended materials, impacts on populations would likely not be detectable.

3.4.3.6.1 Impacts from Military Expended Materials - Munitions

Ingestion of intact military expended materials that are munitions is not likely for most types of expended items because they are too large to be ingested by most marine invertebrates. Though ingestion of intact munitions or large fragments is conceivable in some circumstances (e.g., a relatively large invertebrate such as an octopus or lobster ingesting a small-caliber projectile), such a scenario is unlikely due to the animal's ability to discriminate between food and non-food items. Indiscriminate deposit- and detritus-feeding invertebrates such as some marine worms could potentially ingest munitions fragments that have degraded to sediment size. Metal particles in the water column may be taken up by suspension feeders (e.g., copepods, mussels) (Chiarelli & Roccheri, 2014; Griscom & Fisher, 2004), although metal concentrations in the water are typically much lower than concentrations in sediments (Bazzi, 2014; Brix et al., 2012).

3.4.3.6.1.1 Impacts from Military Expended Materials - Munitions Under Alternative 1

Impacts from Military Expended Materials - Munitions Under Alternative 1 for Training Activities

Under Alternative 1, military expended materials from munitions associated with training activities that could potentially be ingested include non-explosive practice munitions (small- and medium-caliber), small-caliber casings, and fragments from high explosives. These items could be expended throughout most of the Study Area but would be concentrated in the Hawaii Range Complex and Southern California Range Complex. The types of activities that would produce potentially ingestible military expended materials are listed in Appendix B (Activity Stressor Matrices). The quantity of military expended materials associated with each training location is provided in Chapter 3 (Affected Environment and Environmental Consequences). A general discussion of the characteristics of ingestible materials is provided in Section 3.0.3.3.6 (Ingestion Stressors).

It is possible but unlikely that invertebrates would ingest intact munitions. Deposit- and detritus-feeding invertebrates could potentially ingest munitions fragments that have degraded to sediment size, and particulate metals may be taken up by suspension feeders. Impacts on individuals are unlikely, and impacts on populations would probably not be detectable.

The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs and precious coral beds) to avoid potential impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). This mitigation will consequently help avoid potential impacts on invertebrates associated with shallow-water coral reefs and precious coral beds.

ESA-listed abalone species occur in portions of the Southern California Range Complex. Potential impacts on black abalone would be limited to individuals accidentally ingesting small fragments of exploded munitions as they scrape algae or biofilm (a thin layer of microorganisms) off hard substrates in shallow water. Materials are primarily expended far from shore, in the open ocean. It would be possible for military expended materials to fall in offshore waters known to support white abalone, such as Tanner Bank. However, due to the low overall abalone population density and the widely dispersed use of expendable materials, the potential for ingestion and consequent effects would be low. Pursuant to the ESA, the use of military expended materials - munitions during training activities as described under Alternative 1 would have no effect on ESA-listed abalone species.

Impacts from Military Expended Materials - Munitions Under Alternative 1 for Testing Activities

Under Alternative 1, military expended materials from munitions associated with testing activities that could potentially be ingested include non-explosive practice munitions (small- and medium-caliber) and fragments from high-explosives. These items could be expended throughout the Hawaii Range Complex and Southern California Range Complex but are not expended within the HSTT Transit Lane. The types of activities that would produce potentially ingestible military expended materials are listed in Appendix B (Activity Stressor Matrices). The quantity of military expended materials associated with each testing location is provided in Chapter 3 (Affected Environment and Environmental Consequences). A general discussion of the characteristic of ingestible materials in provided in Section 3.0.3.3.6 (Ingestion Stressors).

It is possible but unlikely that invertebrates would ingest intact munitions. Deposit- and detritus-feeding invertebrates could potentially ingest munitions fragments that have degraded to sediment size, and particulate metals may be taken up by suspension feeders. Impacts on individuals are unlikely, and impacts on populations would probably not be detectable.

The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs and precious coral beds) to avoid potential impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). This mitigation will consequently help avoid potential impacts on invertebrates that feed on shallow-water coral reefs and precious coral beds.

ESA-listed black abalone and white abalone occur in portions of the Southern California Range Complex. Potential impacts on abalone would be limited to individuals accidentally ingesting small fragments of exploded munitions as they scrape algae or biofilm off hard substrates in shallow water. Encounters between abalone and munition fragments would be unlikely because military expended materials are primarily used far from shore, in the open ocean. It would be possible for military expended materials to fall in offshore waters known to support white abalone, such as Tanner Bank. However, due to the low overall population density and the widely dispersed use of expendable materials, the potential for ingestion would be low. Pursuant to the ESA, the use of military expended materials - munitions during testing activities as described under Alternative 1 would have no effect on ESA-listed abalone species.

3.4.3.6.1.2 Impacts from Military Expended Materials - Munitions Under Alternative 2

Impacts from Military Expended Materials - Munitions Under Alternative 2 for Training Activities

The locations, types and number of expended military munitions used, and potential ingestion effects would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.6.1.1 (Impacts from Military Expended Materials - Munitions Under Alternative 1) for a discussion of potential ingestion impacts resulting from expended military munitions associated with training activities.

As discussed in Section 3.4.3.6.1.1 (Impacts from Military Expended Materials - Munitions Under Alternative 1), pursuant to the ESA, the use of military expended materials - munitions during training activities as described under Alternative 2 would have no effect on ESA-listed abalone species.

Impacts from Military Expended Materials - Munitions Under Alternative 2 for Testing Activities

The locations, types, and number of expended military munitions used and potential ingestion effects would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.6.1.1 (Impacts from Military Expended Materials - Munitions Under Alternative 1) for a discussion of potential ingestion impacts resulting from expended military munitions associated with testing activities.

As discussed in Section 3.4.3.6.1.1 (Impacts from Military Expended Materials - Munitions Under Alternative 1), pursuant to the ESA, the use of military expended materials - munitions during testing activities as described under Alternative 2 would have no effect on ESA-listed abalone species.

3.4.3.6.1.3 Impacts from Military Expended Materials - Munitions Under the No Action Alternative

Impacts from Military Expended Materials - Munitions Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various physical ingestion stressors (e.g., military expended materials - munitions) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.6.2 Impacts from Military Expended Materials Other Than Munitions

Military expended materials other than munitions include a large number of items such as aerial countermeasures, targets (surface and aerial), mine shapes, ship hulk, small decelerators/parachutes, acoustic countermeasures, sonobuoys, and other various materials such as torpedo accessories, concrete slugs, markers, bathythermographs, and endcaps and pistons. Some expended materials are recovered, including torpedoes, unmanned aerial systems, some targets, mine shapes, metal plates, and bottom placed instruments. Most expendable items, such as targets and target fragments, would sink to the bottom, while materials such as Styrofoam or degraded plastic particles could persist at the surface or in the water column for some time. Ingestion is not likely for most military expended materials because they are too large to be consumed by most marine invertebrates. Though ingestion of intact items on the bottom is conceivable in some circumstances (e.g., a relatively large invertebrate such as an octopus or lobster ingesting a small target fragment), such a scenario is unlikely due to the animal’s ability to discriminate between food and non-food items. Similarly, it is unlikely that an invertebrate at the surface or in the water column would ingest a relatively large expended item as it floats or sinks through the water column.

Degradation of plastic materials could result in microplastic particles being released into the marine environment over time. Eventually, deposit-feeding, detritus-feeding, and filter-feeding invertebrates could ingest these particles, and there is potential for some of the particles to be transferred up trophic levels. Ingestion of plastic particles may result in negative physical and chemical effects to invertebrates. Invertebrates outside the Study Area could encounter microplastic particles if plastic items drift with ocean currents. Currently, overall population-level effects across a broad range of invertebrate species from exposures to microplastic particles are uncertain (Kaposi et al., 2014). Navy training and testing activities would result in a small amount of plastic particles introduced to the marine environment compared to other sources, as many military expended materials are not composed of plastic. The vast majority of marine debris by volume and ingestion potential consists of or is derived from non-military items (Kershaw et al., 2011).

Marine invertebrates may occasionally encounter chaff fibers and incidentally ingest chaff when they ingest prey or water. Literature reviews and controlled experiments suggest that chaff poses little environmental risk to marine organisms at concentrations that could reasonably occur from military training and testing (Arfsten et al., 2002; U.S. Department of the Navy, 1999).

3.4.3.6.2.1 Impacts from Military Expended Materials Other Than Munitions Under Alternative 1

Impacts from Military Expended Materials Other Than Munitions Under Alternative 1 for Training Activities

Under Alternative 1, a variety of potentially ingestible military expended materials would be released to the marine environment by Navy training activities, including target fragments, chaff, canisters, and flare casings. These items could be expended throughout the Study Area, although most would be expended in the Hawaii Range Complex and Southern California Range Complex. Comparatively few items would be expended in the HSTT Transit Corridor. The types of activities that would produce potentially ingestible military expended materials are listed in Appendix B (Activity Stressor Matrices). The quantity of military expended materials associated with each training location is provided in Chapter 3 (Affected Environment and Environmental Consequences). A general discussion of the characteristics of ingestible materials is provided in Section 3.0.3.3.6 (Ingestion Stressors).

Most invertebrates would not be able to ingest most intact expended items. Ingestion would be limited to small items such as chaff, and fragments of larger items such as targets. Deposit- and detritus-feeding invertebrates could potentially ingest small items that have degraded to sediment size, and particulate metals may be taken up by suspension feeders. In addition, small plastic pieces may be consumed by a wide variety of invertebrates with diverse feeding methods (detritivores, planktivores, deposit-feeders, filter-feeders, and suspension-feeders) in the water column or on the bottom. Adverse effects due to metal pieces on the bottom or in the water column are unlikely. Microplastic particles could affect individuals. Although the potential effects on invertebrate populations due to microplastic ingestion are currently uncertain, Navy activities would result in a small amount of plastic particles introduced to the marine environment compared to other sources. Overall, impacts on invertebrate populations due to military expended materials other than munitions would probably not be detectable.

ESA-listed abalone species occur in portions of the Southern California Range Complex. Potential impacts on abalones would be limited to individuals accidentally ingesting small fragments of degraded military expended materials as they scrape algae or biofilm off hard substrates in shallow water. Materials are primarily expended far from shore, in the open ocean. It would be possible for military expended materials to fall in offshore waters known to support white abalone, such as Tanner Bank. However, due to the low overall population density and the widely dispersed use of expendable materials, the potential for ingestion would be low. Pursuant to the ESA, the use of military expended materials other than munitions during training activities as described under Alternative 1 would have no effect on ESA-listed abalone species.

Impacts from Military Expended Materials Other Than Munitions Under Alternative 1 for Testing Activities

Under Alternative 1, a variety of potentially ingestible military expended materials would be released to the marine environment by Navy testing activities, including target fragments, chaff, canisters, and flare casings. These items could be expended throughout the Hawaii Range Complex and Southern California Range Complex. The types of activities that would produce potentially ingestible military expended materials are listed in Appendix B (Activity Stressor Matrices). The quantity of military expended materials associated with each testing location is provided in Chapter 3 (Affected Environment and Environmental Consequences). A general discussion of the characteristics of ingestible materials in provided is Section 3.0.3.3.6 (Ingestion Stressors).

Most invertebrates would not be able to ingest most intact expended items. Ingestion would be limited to small items such as chaff, and fragments of larger items. Deposit- and detritus-feeding invertebrates could potentially ingest small items that have degraded to sediment size, and particulate metals may be taken up by suspension feeders. Small plastic pieces may be consumed by invertebrates with a wide diversity of feeding methods in the water column or on the bottom. In addition, products resulting from the breakdown of biodegradable polymer would be introduced to the water column.

The types of invertebrates that could ingest these particles would vary as the material degrades into smaller particles with increasing amount of time in the water. Adverse effects due to metal pieces on the bottom or in the water column are unlikely. Microplastic particles could affect individuals. Although the potential effects on invertebrate populations due to microplastic ingestion are currently uncertain, Navy activities would result in a small amount of plastic particles introduced to the marine environment. Overall, impacts on invertebrate populations due to military expended materials other than munitions would probably not be detectable.

ESA-listed abalone species occur in portions of the Southern California Range Complex. Potential impacts on abalones would be limited to individuals accidentally ingesting small fragments of degraded military expended materials as they scrape algae or biofilm off hard substrates in shallow water. Materials are primarily expended far from shore, in the open ocean. It would be possible for military expended materials to fall in offshore waters known to support white abalone, such as Tanner Bank. However, due to the low overall population density and the widely dispersed use of expendable materials, the potential for ingestion would be low. Pursuant to the ESA, the use of military expended materials other than munitions during testing activities as described under Alternative 1 would have no effect on ESA-listed abalone species.

3.4.3.6.2.2 Impacts from Military Expended Materials Other Than Munitions Under Alternative 2

<u>Impacts from Military Expended Materials Other Than Munitions Under Alternative 2 for Training Activities</u>

Under Alternative 2, the locations and types of military expended materials used would be the same as those of Alternative 1. Under Alternative 2, there would be a small increase in the number of some items expended (e.g., subsurface and surface targets, non-explosive buoys and sonobuoys, and small decelerators/parachutes) in the Study Area. This relatively small increase in the total number of items expended would not be expected to result in substantive changes to the type or degree of impacts on invertebrates. Refer to Section 3.4.3.6.2.1 (Impacts from Military Expended Materials Other Than Munitions Under Alternative 1) for a discussion of potential ingestion impacts resulting from military expended materials other than munitions associated with training activities.

As discussed in Section 3.4.3.6.2.1 (Impacts from Military Expended Materials Other Than Munitions Under Alternative 1), pursuant to the ESA, the use of military expended materials other than munitions during training activities as described under Alternative 2 would have no effect on ESA-listed abalone species.

Impacts from Military Expended Materials Other Than Munitions Under Alternative 2 for Testing Activities

Under Alternative 2, the locations and types of military expended materials used would be the same as those under Alternative 1. Under Alternative 2, there would be a small increase in the number of some items expended (e.g., targets, non-explosive buoys and sonobuoys, and small decelerators/parachutes) in the Hawaii Range Complex and Southern California Range Complex. This small increase in the total number of items expended would not be expected to result in substantive changes to the type or degree of impacts on invertebrates. Refer to Section 3.4.3.6.2.1 (Impacts from Military Expended Materials Other Than Munitions Under Alternative 1) for a discussion of potential ingestion impacts resulting from military expended materials other than munitions associated with testing activities.

As discussed in Section 3.4.3.6.2.1 (Impacts from Military Expended Materials Other Than Munitions Under Alternative 1), pursuant to the ESA, the use of military expended materials other than munitions during testing activities as described under Alternative 2 would have no effect on ESA-listed abalone species.

3.4.3.6.2.3 Impacts from Military Expended Materials Other Than Munitions Under the No Action Alternative

Impacts from Military Expended Materials Other Than Munitions Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various physical ingestion stressors (e.g., military expended materials other than munitions) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.7 Secondary Stressors

This section analyzes potential impacts on marine invertebrates exposed to stressors indirectly through impacts on their habitat (sediment or water quality) or prey. The assessment of potential water and sediment quality stressors refers to previous sections (Section 3.2, Sediments and Water Quality), and addresses specific activities in local environments that may affect invertebrate habitats. The terms “indirect” and “secondary” do not imply reduced severity of environmental consequences, but instead describe how the impact may occur in an organism or its ecosystem. Stressors from Navy training and testing activities that could pose indirect impacts on marine invertebrates via habitat or prey include: (1) explosives and explosive byproducts, (2) chemicals other than explosives, and (3) metals.

Secondary or indirect stressors may impact benthic and pelagic invertebrates, gametes, eggs, and larvae by changes to sediment and water quality. Physical and biological features of ESA-listed black abalone critical habitat are defined in Section 3.4.2.2.1.1 (Status and Management). These features are rocky substrate, food resources, juvenile settlement habitat, suitable water quality, and suitable nearshore circulation patterns. Exemptions from critical habitat designation include areas offshore of San Nicolas and San Clemente Islands. However, exemption does not preclude analysis of ESA-listed black abalones. Potential impacts to rocky substrate would be associated with physical effects such as breakage or covering. Potential impacts to water quality would be associated with introduction of metal, plastic, or chemical substances into the water column.

Explosives and Explosive Byproducts

Secondary impacts on invertebrates resulting from explosions at the surface, in the water column, or on the bottom would be associated with changes to habitat structure and effects to prey species. Most explosions on the bottom would occur in soft bottom habitat and would displace some amount of sediment, potentially resulting in cratering. However, water movement would redistribute the affected sediment over time. A small amount of sediment would be suspended in the water column temporarily but would resettle to the bottom. There would be no overall reduction in the surface area or volume of sediment available to benthic species that occur on the bottom or within the substrate. Activities that inadvertently result in explosions on or near hard bottom habitat or reefs could break hard structures and reduce the amount of colonizing surface available to encrusting organisms (e.g., corals, sponges).

Explosions in the water column or on the bottom could impact invertebrate prey species. Some species of most invertebrate taxa prey upon other invertebrate species, with prey items ranging in size from zooplankton to relatively large shrimps and crabs. Therefore, in a strict sense, mortality to invertebrate species resulting from an explosion may represent a reduction in prey to other invertebrate species. A few invertebrates such as squid and some jellyfish prey upon fish, although jellyfish capture fish passively rather than through active pursuit. Therefore, fish mortality resulting from an explosion would reduce the number of potential prey items for invertebrates that consume fish. In addition to mortality, fish located near a detonation would likely be startled and leave the area, temporarily reducing prey availability until the affected area is repopulated.

Some invertebrates (e.g., worms, crustaceans, sea stars) are scavengers that would feed on any vertebrate or invertebrate animal that is killed or significantly impaired by an explosion. Therefore, scavenging invertebrates that are not killed or injured themselves could benefit from physical impacts on other animals resulting from explosions in the water column or on the bottom.

High-order explosions consume most of the explosive material, leaving only small or residual amounts of explosives and combustion products. Most of the combustion products of trinitrotoluene (i.e., TNT), such as carbon dioxide and nitrogen, are common seawater constituents, although other products such as carbon monoxide are also produced (Becker, 1995). Other explosive compounds may produce different combustion products. All combustion products are rapidly diluted by ocean currents and circulation (see Section 3.2.3.1, Explosives and Explosives Byproducts). Therefore, explosives byproducts from high-order detonations would not degrade sediment or water quality or result in indirect stressors to marine invertebrates. Low-order detonations and unexploded munitions present an elevated potential for effects on marine invertebrates. Deposition of undetonated explosive materials into the marine environment can be reasonably estimated by the known failure and low-order detonation rates of high explosives (Section 3.2.3.1, Explosives and Explosives Byproducts). Explosive material not completely consumed during a detonation from munitions disposal and mine clearing training are collected after the activities are completed; therefore, potential impacts are likely inconsequential and not detectable for these activities.

Exposure to relatively high concentrations of various explosive materials in sediments and in the water may result in lethal and sub-lethal effects to invertebrates. The type and magnitude of effects appear to be different among various invertebrate species and are also influenced by the type of explosive material and physical characteristics of the affected water and sediment. For example, lethal toxicity has been reported in some invertebrate species (e.g., the amphipod *Eohaustorius estuarius*) exposed to trinitrotoluene (i.e., TNT), while mortality has not been found in other species (e.g., the polychaete worm *Neanthes arenaceodentata*), even when exposed to very high concentrations (Rosen & Lotufo, 2005). Exposure to water-borne explosive materials has been found to affect reproduction or larval development in bivalve, sea urchin, and polychaete worm species (Lotufo et al., 2013). Invertebrates on the bottom may be exposed to explosive materials by ingesting contaminated sediment particles, in addition to being exposed to materials in the overlying water column or in voids in the sediment (for burrowing invertebrates). However, toxicity and other sub-lethal effects have often been associated with exposure to higher concentrations of explosive materials than the concentrations expected to occur in marine or estuarine waters of the Study Area due to training and testing activities.

Indirect impacts of explosives and unexploded munitions on marine invertebrates via sediment are possible near the munitions. Rosen and Lotufo (2010) exposed mussels and deposit-feeding amphipods and polychaete worms to levels of TNT and royal demolition explosive potentially associated with a breached munition or low-order detonation. The authors found concentrations in the sediment above toxicity levels within about 1 in. of the materials, although no statistical increase in mortality was observed for any species. Concentrations causing toxicity were not found in the water column. Explosive material in the marine environment is readily degraded via several biotic and abiotic pathways, as discussed in Section 3.2.3.1 (Explosives and Explosives Byproducts). The results of studies of explosive material deposition at munitions disposal sites and active military water ranges suggest that explosives and explosives residues pose little risk to fauna living in direct contact with munitions, and that sediment is not a significant sink for these materials (Kelley et al., 2016; Koide et al., 2016; Smith & Marx, 2016). Munitions constituents and degradation products would likely be detectable only within a few feet of a degrading munition, and the spatial range of toxic sediment conditions could be less (inches). It has been suggested that the risk of toxicity to invertebrates in realistic exposure scenarios is negligible (Lotufo et al., 2013). Indirect impacts of explosives and unexploded munitions on marine invertebrates via water are likely to be inconsequential. Most explosives and explosive degradation products have relatively low solubility in seawater. This means that dissolution occurs extremely slowly, and harmful concentrations of explosives and degradation products are not likely to occur in the water column. Also, the low concentration of materials delivered slowly into the water column is readily diluted by ocean currents and would be unlikely to concentrate in toxic levels. Filter feeders such as sponges or some marine worms would be exposed to chemical byproducts only in the immediate vicinity of degrading explosives (inches or less) due to the low solubility and dilution by water currents. While marine invertebrates may be adversely impacted by the indirect effects of degrading explosives via water, this is unlikely in realistic scenarios.

Impacts on marine invertebrates, including zooplankton, eggs, and larvae, are likely only within a very small radius of the munition (potentially inches). These impacts may continue as the munition degrades over decades (Section 3.2.3.1, Explosives and Explosives Byproducts). Because most munitions are deployed as projectiles, multiple unexploded or low-order detonations would not likely accumulate on spatial scales as small as feet to inches; therefore, potential impacts are likely to remain local and widely separated. Explosives, explosives byproducts, and unexploded munitions would therefore generally not be present in these habitats.

Chemicals Other Than Explosives

Several Navy training and testing activities introduce potentially harmful chemicals into the marine environment, primarily propellants and combustion products, other fuels, polychlorinated biphenyls in target vessels, other chemicals associated with munitions, and simulants (Section 3.2.3.2, Chemicals Other Than Explosives). Ammonium perchlorate (a rocket and missile propellant) is the most common chemical used. Perchlorate is known to occur naturally in nitrate salts, such as those from Chile, and it may be formed by atmospheric processes such as lightning and reactions between ozone and sodium chloride in the air (associated with evaporated seawater) (Dasgupta et al., 2005; Sijimol & Mohan, 2014; U.S. Environmental Protection Agency, 2014). Perchlorate may impact metabolic processes in plants and animals. Effects have been found in earthworms and aquatic (freshwater) insects (Smith, 2002; Srinivasan & Viraraghavan, 2009), although effects specific to marine invertebrates are unknown. Other chemicals with potential for adverse effects to invertebrates include some propellant combustion products, such as hydrogen cyanide and ammonia.

Potential impacts on sediments and seawater resulting from use of chemicals are discussed in Section 3.2.3.2 (Chemicals Other Than Explosives). Rockets and missiles are highly efficient at consuming propellants (for example, over 99.9 percent of perchlorate is typically consumed) and, therefore, very little residual material would enter the water column. Additionally, perchlorate does not readily absorb into sediments, potentially reducing the risk to deposit- and detritus-feeding invertebrates. Torpedoes are expended in the water and, therefore, torpedo propellant (e.g., Otto Fuel II) combustion products would enter the marine environment. Overall, analysis concludes that impacts on sediments and water quality would be minimal for several reasons. The size of the area affected is large and, therefore, chemicals would not be concentrated. Most propellant combustion byproducts are benign, and those of concern (e.g., hydrogen cyanide) would be quickly diluted. Most propellants are consumed during normal operations, and the failure rate of munitions using propellants and other combustible materials is low. Most byproducts of Otto Fuel II combustion occur naturally in seawater, and most torpedoes are recovered after use, limiting the potential for unconsumed fuel to enter the water. In addition, most constituents are readily degraded by biotic and abiotic processes. Concentrations of chemicals in sediment and water are not likely to cause injury or mortality to marine invertebrates, gametes, eggs, or larvae.

Target vessels are only used during sinking exercises, which occur infrequently. Polychlorinated biphenyls may be present in certain solid materials (e.g., insulation, wires, felts, and rubber gaskets) on target vessels. The vessels are selected from a list of Navy-approved vessels that have been cleaned in accordance with USEPA guidelines. Sinking exercises must be conducted at least 50 NM offshore and in water at least 6,000 ft. deep. USEPA estimates that as much as 100 lb. of polychlorinated biphenyls remain onboard sunken target vessels. USEPA considers the contaminant levels released during the sinking of a target to be within the standards of the Marine Protection, Research, and Sanctuaries Act (16 United States Code 1341, et seq.). Under a 2014 agreement with USEPA, the Navy will not likely use aircraft carriers or submarines as the targets for a sinking exercise. As discussed in Section 3.2.3.2 (Chemicals Other Than Explosives), based on these considerations, polychlorinated biphenyls are not evaluated further as a secondary stressor to invertebrate habitats.

Metals

Certain metals and metal-containing compounds (e.g., cadmium, chromium, lead, mercury, zinc, copper, manganese, and many others) are harmful to marine invertebrates at various concentrations above background levels (Chan et al., 2012; Negri et al., 2002; Wang & Rainbow, 2008). For example, physiological effects in crabs, limpets, and mussels due to copper exposure were reported (Brown et al., 2004), although the effects were found at concentrations substantially higher than those likely to be encountered due to Navy expended materials. Metals are introduced into seawater and sediments as a result of training and testing activities involving vessel hulks, targets, munitions, and other military expended materials (see Section 3.2.3.3, Metals). Some effects due to metals result from the concentrating effects of bioaccumulation, which is not discussed in this section. Bioaccumulation issues are discussed in the *Ecosystem Technical Report for the Hawaii-Southern California Training and Testing (HSTT) Environmental Impact Statement* (U.S. Department of the Navy, 2013b). Secondary effects may occur when marine invertebrates are exposed by contact with the metal, contact with trace amounts in the sediment or water (e.g., from leached metals), and ingestion of contaminated sediments.

Because metals tend to precipitate out of seawater and often concentrate in sediments, potential adverse indirect impacts are much more likely via sediment than water (Zhao et al., 2012). However, studies have found the concentrations of metals in the sediments of military ranges (e.g., Navy training areas such as Vieques, Puerto Rico) or munitions disposal sites, where deposition of metals is very high, to rarely be above biological effects levels (Section 3.2.3.3, Metals). For example, researchers sampled areas associated with Vieques in which live ammunition and weapons were used and found generally low concentrations of metals in the sediment (Kelley et al., 2016; Pait et al., 2010). Comparison with guidelines suggested by the National Oceanic and Atmospheric Administration's National Status and Trends Program showed that average metal concentrations were below threshold effects levels for all constituents except copper, and were below probable effects levels for all constituents. The concentration of munitions at Vieques is substantially greater than would occur in the HSTT Study Area. Evidence from a number of studies at military ranges and disposal sites indicates metal contamination is very localized (Briggs et al., 2016; Kelley et al., 2016; Koide et al., 2016). Impacts on invertebrates, eggs, or larvae would likely be limited to exposure in the sediment within a few inches of the object. Refer to Section 3.2.3.3 (Metals) for more detailed study results of metal contamination in sediments at military ranges.

Concentrations of metals in seawater affected by Navy training and testing activities are unlikely to be high enough to cause injury or mortality to marine invertebrates. Benthic invertebrates occurring very near (within a few inches of) Navy-derived materials on the seafloor could be impacted by associated metal concentrations, but this is expected to affect relatively few individuals.

3.4.3.7.1 Impacts on Habitat

As discussed in Section 3.4.3.7 (Secondary Stressors), impacts on invertebrate habitat resulting from explosives, explosives byproducts, unexploded munitions, metals, and chemicals would be minor overall, and the possibility of population-level impacts on marine invertebrates is remote. Explosions would temporarily disturb soft bottom sediments, and explosions that might occur on unknown hard bottom areas would potentially damage hard structures. The effects of these activities would likely be undetectable at the population or subpopulation level for widespread or common invertebrate species. The potential for impacts would be of greater concern for species with limited spatial distribution, such as abalones. Potential impacts on ESA-listed abalone species are discussed below. Individual invertebrates could be killed, injured, or experience physiological effects due to exposure to metals and chemical materials (including explosives materials) in the water column or on the bottom, but these effects would be very localized.

Deposition of metal materials would provide new hard substrate that could be colonized by encrusting invertebrates (e.g., sponges, barnacles, hydrozoans, corals). The increased area of artificial hard habitat could therefore provide a benefit to some invertebrate species although, similar to the preceding discussion, any positive impacts would likely be undetectable at the population level. In addition, invertebrate communities on artificial substrate may be different than those found in adjacent natural substrate.

The potential for explosions occurring near the surface to damage seafloor resources such as ESA-listed coral habitat is considered negligible. The largest explosives are used more than 12 NM from shore where water depth is typically greater than 90 m, and explosive effects would not extend to the bottom at locations seaward of the coastal zone due to vertical compression of explosive impacts around the detonation point. Bottom explosions would not occur on known live hard bottom areas. Therefore, impacts on habitat potentially supporting ESA-listed abalone species would be limited to activities that are inadvertently conducted on or near unknown habitat areas. Any impacts on hard structure could reduce the amount of adequate substrate available to the black abalone. Hard substrate is considered an essential physical feature of black abalone critical habitat. Although critical habitat is not designated for white abalone, hard structure is an important habitat feature for this species as well. Due to the possibility of inadvertent impacts on hard structure, explosions may affect ESA-listed abalone species. The Navy has consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.4.3.7.2 Impacts on Prey Availability

As discussed in Section 3.4.3.7 (Secondary Stressors), impacts on invertebrate prey availability (including vegetation and phytoplankton) resulting from explosives, explosives byproducts, unexploded munitions, metals, and chemicals would likely be negligible overall and population-level impacts on marine invertebrates are not expected. Because individuals of many invertebrate taxa prey on other invertebrates, mortality resulting from explosions or exposure to metals or chemical materials would reduce the number of invertebrate prey items available. A few species prey upon fish, and explosions and exposure to metals and chemical materials could result in a minor reduction in the number of fish available. However, as discussed in Section 3.6.3.7 (Secondary Stressors), explosive materials, metals, and chemicals would have a negligible effect on fishes. Therefore, secondary effects to invertebrates due to reduced fish prey availability are unlikely. Any vertebrate or invertebrate animal killed or significantly impaired by Navy activities could potentially represent an increase in food availability for scavenging invertebrates. None of the effects described above would likely be detectable at the population or subpopulation level. Pursuant to the ESA, potential effects to prey availability would have no effect on ESA-listed abalone species.

3.4.4 Summary of Potential Impacts on Invertebrates

3.4.4.1 Combined Impacts of All Stressors Under Alternative 1

As described in Section 3.0.3.5 (Resource-Specific Impacts Analysis for Multiple Stressors), this section evaluates the potential for combined impacts of all stressors from the Proposed Action. The analysis and conclusions for the potential impacts from each of the individual stressors are discussed in the sections above and, for ESA listed species, summarized in Section 3.4.5 (Endangered Species Act Determinations). Stressors associated with Navy training and testing activities do not typically occur in isolation but rather occur in some combination. For example, mine neutralization activities include elements of acoustic, physical disturbance and strike, entanglement, ingestion, and secondary stressors that are all coincident in space and time. An analysis of the combined impacts of all stressors considers the potential consequences of additive stressors and synergistic stressors, as described below. This analysis makes the assumption that the majority of exposures to stressors are non-lethal, and instead focuses on consequences potentially impacting the organism’s fitness (e.g., physiology, behavior, reproductive potential). Invertebrates in the Study Area could potentially be impacted by introduction of invasive species due to direct predation, competition for prey, or displacement from suitable habitat. Invasive species could be introduced by growth on vessel hulls or discharges of bilge water. Refer to Section 3.2.1.2.2 (Federal Standards and Guidelines) for a discussion of naval vessel discharges.

There are generally two ways that a marine invertebrate could be exposed to multiple additive stressors. The first would be if an invertebrate were exposed to multiple sources of stress from a single event or activity within a single testing or training event (e.g., a mine warfare event may include the use of a sound source and a vessel). The potential for a combination of these impacts from a single activity would depend on the range to effects of each of the stressors and the response or lack of response to that stressor. Most of the activities proposed under Alternative 1 generally involve the use of moving platforms (e.g., ships, torpedoes) that may produce one or more stressors; therefore, if invertebrates were within the potential impact range of those activities, they may be impacted by multiple stressors simultaneously. Individual stressors that would otherwise have minimal to no impact, may combine to have a measurable response. However, due to the wide dispersion of stressors, speed of the platforms, and general dynamic movement of many training and testing activities, it is unlikely that a pelagic or mobile marine invertebrate would occur in the potential impact range of multiple sources or sequential exercises. Impacts would be more likely to occur to sessile and slow-moving species, and in areas where training and testing activities are concentrated (e.g., near naval port facilities, anchorages, and mine ranges).

Secondly, an invertebrate could be exposed to multiple training and testing activities over the course of its life. It is unlikely that mobile or migratory marine invertebrates that occur within the water column would be exposed to multiple activities during their lifespan because they are relatively short lived, and most Navy training and testing activities impact small, widely dispersed areas, often during the day when many pelagic invertebrates have migrated away from the surface. It is much more likely that stationary organisms or those that only move over a small range (e.g., corals, sponges, worms, and sea urchins) would be exposed to multiple stressors for a prolonged duration. A few activities occur at a fixed point (e.g., port security training, pierside sonar testing), and could potentially affect the same sessile or sedentary individual invertebrates. However, due to invertebrate distribution and lifespan, few individuals compared to overall population size would likely be affected repeatedly by the same stressor, and the impacts would be mostly non-lethal. Other Navy activities may occur in the same general area (e.g., gunnery activities), but do not occur at the same specific point each time and would therefore be unlikely to affect the same individual invertebrates.

Multiple stressors may also have synergistic effects. For example, although it has been suggested that military activities may contribute to coral decline, global impacts are driven primarily by synergistic impacts of pollution, overfishing, climate change, sedimentation, and naturally-occurring stressors such as predator outbreaks and storms, among other factors (Ban et al., 2014; Muthukrishnan & Fong, 2014). As discussed in the analyses above, marine invertebrates are not particularly susceptible to energy, entanglement, or ingestion stressors resulting from Navy activities; therefore, the potential for Navy stressors to result in additive or synergistic consequences is most likely limited to acoustic, physical strike and disturbance, and secondary stressors. The potential synergistic interactions of multiple stressors resulting from Navy activities are difficult to predict quantitatively. Even for shallow-water corals, an exceptionally well-studied resource, predictions of the consequences of multiple stressors are semi-quantitative and generalized predictions remain qualitative (Hughes & Connell, 1999; Norstrom et al., 2009).

Although potential impacts on marine invertebrate species from training and testing activities under Alternative 1 may include injury and mortality, in addition to other effects such as physiological stress, masking, and behavioral effects, the impacts are not expected to lead to long-term consequences for invertebrate populations or subpopulations. The number of invertebrates impacted is expected to be small relative to overall population sizes, and would not be expected to yield any lasting effects on the survival, growth, recruitment, or reproduction of any invertebrate species. The potential impacts anticipated on ESA-listed species from Alternative 1 are summarized in Section 3.4.5 (Endangered Species Act Determinations). For a discussion of cumulative impacts, see Chapter 4 (Cumulative Impacts). For a discussion of mitigation, see Chapter 5 (Mitigation).

3.4.4.2 Combined Impacts of All Stressors Under Alternative 2

Training and testing activities proposed under Alternative 2 would represent an increase over what is proposed for Alternative 1. However, these minor differences are not expected to substantially increase the potential for impacts over what is analyzed for Alternative 1. The analysis presented in Section 3.4.4.1 (Combined Impacts of All Stressors Under Alternative 1) would similarly apply to Alternative 2. The combined impacts of all stressors for training and testing activities under Alternative 2 are not expected to lead to long-term consequences for invertebrate populations or subpopulations. The number of invertebrates impacted is expected to be small relative to overall population sizes and would not be expected to yield any lasting effects on the survival, growth, recruitment, or reproduction of any invertebrate species.

3.4.4.3 Combined Impacts of All Stressors Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training or testing activities in the HSTT Study Area. All stressors associated with Navy training and testing activities would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.5 Endangered Species Act Determinations

Pursuant to the ESA, the Navy has consulted with NMFS on Alternative 1 (the Preferred Alternative) as required by section 7(a)(2) of the ESA and determined that training and testing activities may affect the black and white abalone and may affect designated black abalone critical habitat.

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REFERENCES

Aggio, J. F., R. Tieu, A. Wei, and C. D. Derby. (2012). Oesophageal chemoreceptors of blue crabs, *Callinectes sapidus*, sense chemical deterrents and can block ingestion of food. *The Journal of Experimental Biology, 215*(10), 1700–1710.

Aguilar de Soto, N., N. Delorme, J. Atkins, S. Howard, J. Williams, and M. Johnson. (2013). Anthropogenic noise causes body malformations and delays development in marine larvae. *Scientific Reports, 3*(2831), 2831.

André, M., M. Solé, M. Lenoir, M. Durfort, C. Quero, A. Mas, A. Lombarte, M. van der Schaar, M. Lopez-Bejar, M. Morell, S. Zaugg, and L. Houégnigan. (2011). Low-frequency sounds induce acoustic trauma in cephalopods. *Frontiers in Ecology and the Environment, 9*(9), 489–493.

Andriguetto-Filho, J. M., A. Ostrensky, M. R. Pie, U. A. Silva, and W. A. Boeger. (2005). Evaluating the impact of seismic prospecting on artisanal shrimp fisheries. *Continental Shelf Research, 25*, 1720–1727.

Aplin, J. A. (1947). The effect of explosives on marine life. *California Fish and Game, 33*, 23–30.

Appeltans, W., P. Bouchet, G. A. Boxshall, K. Fauchald, D. P. Gordon, B. W. Hoeksema, G. C. B. Poore, R. W. M. van Soest, S. Stöhr, T. C. Walter, and M. J. Costello. (2010). *World Register of Marine Species*. Retrieved from http://www.marinespecies.org/index.php.

Arfsten, D. P., C. L. Wilson, and B. J. Spargo. (2002). Radio frequency chaff: The effects of its use in training on the environment. *Ecotoxicology and Environmental Safety, 53*, 1–11.

Arifin, L., A. Bakti, A. Virgota, L. P. A. Damayanti, T. H. U. Radiman, A. Retnowulan, Hernawati, A. Sabil, and D. Robbe. (2012). Biorock Reef Restoration in Gili Trawangan, North Lombok, Indonesia. In T. J. Goreau & R. K. T. Trench (Eds.), *Innovative Methods of Marine Ecosystem Restoration* (pp. 59–80). Boca Raton, FL: CRC Press.

Ateweberhan, M., and T. R. McClanahan. (2010). Relationship between historical sea-surface temperature variability and climate change-induced coral mortality in the western Indian Ocean. *Marine Pollution Bulletin, 60*(7), 964–970.

Ateweberhan, M., D. A. Feary, S. Keshavmurthy, A. Chen, M. H. Schleyer, and C. R. Sheppard. (2013). Climate change impacts on coral reefs: synergies with local effects, possibilities for acclimation, and management implications. *Marine Pollution Bulletin, 74*(2), 526–539.

Au, W. W. L., and K. Banks. (1998). The acoustics of the snapping shrimp *Synalpheus parneomeris* in Kaneohe Bay. *The Journal of the Acoustical Society of America, 103*(1), 41–47.

Au, W. W. L., J. K. B. Ford, J. K. Horne, and K. A. N. Allman. (2004). Echolocation signals of free-ranging killer whales (*Orcinus orca*) and modeling of foraging for chinook salmon (*Oncorhynchus tshawytscha*). *The Journal of the Acoustical Society of America, 115*(2), 901–909.

Baco, A. R. (2007). Exploration for deep-sea corals on North Pacific seamounts and islands. *Oceanography, 20*(4), 108–117.

Bahr, K. D., P. L. Jokiel, and K. S. Rodgers. (2015). The 2014 coral bleaching and freshwater flood events in Kaneohe Bay, Hawaii. *Peer-reviewed Journal, 3*, e1136.

Bahr, K. D., P. L. Jokiel, and K. u. S. Rodgers. (2016). Relative sensitivity of five Hawaiian coral species to high temperature under high-pCO_2 conditions. *Coral Reefs, 35*(2), 729–738.

Bahr, K. D., K. D. Rodgers, and P. L. Jokiel. (2017). Impact of Three Bleaching Events on the Reef Resiliency of Kaneohe Bay, Hawaii. *Frontiers in Marine Science, 4*(398), 1–13.

Baker, E. K., K. A. Puglise, and P. T. Harris. (2016). *Mesophotic coral ecosystems — A lifeboat for coral reefs?* Arendal, Norway and Nairobi, Kenya: The United Nations Environment Programme and Global Resources Information Database.

Ban, S. S., N. A. J. Graham, and S. R. Connolly. (2014). Evidence for multiple stressor interactions and effects on coral reefs. *Global Change Biology, 20*, 681–697.

Bazzi, A. O. (2014). Heavy metals in seawater, sediments and marine organisms in the Gulf of Chabahar, Oman Sea. *Journal of Oceanography and Marine Science, 5*(3), 20–29.

Becker, N. M. (1995). *Fate of Selected High Explosives in the Environment: A Literature Review* (LAUR-95-1018). Los Alamos, NM: Los Alamos National Laboratories.

Bernardino, A. F., and C. R. Smith. (2010). Community structure of infaunal macrobenthos around vestimentiferan thickets at the San Clemente cold seep, NE Pacific. *Marine Ecology* 608–621.

Bernhardt, P. (1979). *A Key to the Nemertea from the Intertidal Zone of the Coast of California*. Long Beach, CA.

Bernstein, B., K. Merkel, B. Chensey, and M. Sutula. (2011). *Recommendations for a Southern California Regional Eelgrass Monitoring Program*. Ojai, San Diego, Long Beach, and Coasta Mesa, CA: Southern California Coastal Water Research Project.

Bessell-Browne, P., A. P. Negri, R. Fisher, P. L. Clode, and R. Jones. (2017). Cumulative impacts: thermally bleached corals have reduced capacity to clear deposited sediment. *Scientific Reports, 7*(2716), 14.

Bickel, S. L., J. D. Malloy Hammond, and K. W. Tang. (2011). Boat-generated turbulence as a potential source of mortality among copepods. *Journal of Experimental Marine Biology and Ecology, 401*(1–2), 105–109.

Bilkovic, D., M. Mitchell, J. Davis, E. Andrews, A. King, P. Mason, J. Herman, N. Tahvildari, and J. Davis. (2017). *Review of boat wake wave impacts on shoreline erosion and potential solutions for the Chesapeake Bay* (STAC Publication Number 17-002). Edgewater, MD: Chesapeake Bay Program Scientific and Technical Advisory Committee.

Bishop, M. J. (2008). Displacement of epifauna from seagrass blades by boat wake. *Journal of Experimental Marine Biology and Ecology, 354*(1), 111–118.

Boland, G. S., P. J. Etnoyer, C. R. Fisher, and E. L. Hickerson. (2016). State of Deep-Sea Coral and Sponge Ecosystems in the Gulf of Mexico Region: Texas to the Florida Straits. In NOAA (Ed.), *The State of Deep-Sea Coral and Sponge Ecosystems in the United States* (Vol. NOAA Technical Memorandum NMFS-OHC-3, pp. 11–11–11–59). Silver Spring, MD: National Oceanic and Atmospheric Administration.

Brainard, R. E., C. Birkeland, C. M. Eakin, P. McElhany, M. W. Miller, M. Patterson, and G. A. Piniak. (2011). *Status Review Report of 82 Candidate Coral Species Petitioned Under the U.S. Endangered Species Act* (NOAA Technical Memorandum NMFS-PIFSC-27). Honolulu, HI: National Marine Fisheries Service, Pacific Islands Fisheries Science Center.

Brierley, A. S., P. G. Fernandes, M. A. Brandon, F. Armstrong, N. W. Millard, S. D. McPhail, P. Stevenson, M. Pebody, J. Perrett, M. Squires, D. G. Bone, and G. Griffiths. (2003). An investigation of avoidance by Antarctic krill of RRS *James Clark Ross* using the *Autosub*-2 autonomous underwater vehicle. *Fisheries Research, 60*, 569–576.

Briggs, C., S. M. Shjegstad, J. A. K. Silva, and M. H. Edwards. (2016). Distribution of chemical warfare agent, energetics, and metals in sediments at a deep-water discarded military munitions site. *Deep Sea Research Part II: Topical Studies in Oceanography, 128*, 63–69.

Brix, K., P. Gillette, A. Pourmand, T. Capo, and M. Grosell. (2012). The effects of dietary silver on larval growth in the echinoderm *Lytechinus variegatus*. *Archives of Environmental Contamination and Toxicology, 63*(1), 95–100.

Brown, R. J., T. S. Galloway, D. Lowe, M. A. Browne, A. Dissanayake, M. B. Jones, and M. H. Depledge. (2004). Differential sensitivity of three marine invertebrates to copper assessed using multiple biomarkers. *Aquatic Toxicology, 66*, 267–278.

Browne, M. A., S. J. Niven, T. S. Galloway, S. J. Rowland, and R. C. Thompson. (2013). Microplastic moves pollutants and additives to worms, reducing functions linked to health and biodiversity. *Current Biology, 23*(23), 2388–2392.

Brusca, R. C., and G. J. Brusca. (2003). Phylum Cnidaria. In: *Invertebrates* (pp. 219–283). Sunderland, MA: Sinauer Associates, Inc.

Bryan, T. L., and A. Metaxas. (2007). Predicting suitable habitat for deep-water gorgonian corals on the Atlantic and Pacific Continental Margins of North America. *Marine Ecology Progress Series, 330*, 113–126.

Bryant, D., L. Burke, J. McManus, and M. Spalding. (1998). *Reefs at Risk: A Map-Based Indicator of Threats to the World's Coral Reefs*. Washington, DC: World Resources Institute.

Budelmann, B. U. (1992a). Hearing in Crustacea. In D. B. Webster, R. R. Fay, & A. N. Popper (Eds.), *Evolutionary Biology of Hearing* (pp. 131–139). New York, NY: Springer-Verlag.

Budelmann, B. U. (1992b). Hearing in nonarthropod invertebrates. In D. B. Webster, R. R. Fay, & A. N. Popper (Eds.), *Evolutionary Biology of Hearing* (pp. 141–155). New York, NY: Springer-Verlag.

Buhl-Mortensen, L., A. Vanreusel, A. J. Gooday, L. A. Levin, I. G. Priede, P. Buhl-Mortensen, H. Gheerardyn, N. J. King, and M. Raes. (2010). Biological structures as a source of habitat heterogeneity and biodiversity on the deep ocean margins. *Marine Ecology, 31*(1), 21–50.

Bureau of Ocean Energy Management. (2011). *Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species*. Camarillo, CA: U.S. Department of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region.

Burt, J., A. Bartholomew, P. Usseglio, A. Bauman, and P. F. Sale. (2009). Are artificial reefs surrogates of natural habitats for corals and fish in Dubai, United Arab Emirates? *Coral Reefs, 28*, 663–675.

Buscaino, G., F. Filiciotto, M. Gristina, A. Bellante, G. Buffa, V. Di Stefano, V. Maccarrone, G. Tranchida, C. Buscaino, and S. Mazzola. (2011). Acoustic behavior of the European spiny lobster *Palinurus elephas*. *Marine Ecology Progress Series, 441*, 177–184.

Butler, J., M. Neuman, D. Pinkard, R. Kvitek, and G. Cochrane. (2006). The use of multibeam sonar mapping techniques to refine population estimates of the endangered white abalone (*Haliotis sorenseni*). *Fisheries Bulletin, 104*(4), 521–532.

Butler, J., A. DeVogelaere, R. Gustafson, C. Mobley, M. Neuman, D. Richards, S. Rumsey, B. Taylor, and G. VanBlaricom. (2009). *Status Review Report for Black Abalone (Haliotis cracherodii Leach, 1814)*. Long Beach, CA: National Marine Fisheries Service, Southwest Region.

Cairns, S. D. (2007). Deep-water corals: An overview with special reference to diversity and distribution of deep-water Scleractinian corals. *Bulletin of Marine Science, 81*(3), 311–322.

Carpenter, R. C., C. A. Lantz, E. Shaw, and P. J. Edmunds. (2018). Responses of coral reef community metabolism in flumes to ocean acidification. *Marine Biology, 165*(66), 1–13.

Castro, P., and M. E. Huber. (2000a). Marine animals without a backbone. In *Marine Biology* (3rd ed., pp. 104–138). New York, NY: McGraw-Hill.

Castro, P., and M. E. Huber. (2000b). Marine prokaryotes, protists, fungi, and plants. In *Marine Biology* (3rd ed., pp. 83–103). New York, NY: McGraw-Hill.

Cato, D. H., and M. J. Bell. (1992). *Ultrasonic Ambient Noise in Australian Shallow Waters at Frequencies up to 200 kHz*. Ascot Vale, Australia: Materials Research Laboratory.

Celi, M., F. Filiciotto, D. Parrinello, G. Buscaino, M. A. Damiano, A. Cuttitta, S. D'Angelo, S. Mazzola, and M. Vazzana. (2013). Physiological and agonistic behavioural response of *Procambarus clarkii* to an acoustic stimulus. *The Journal of Experimental Biology, 216*, 709–718.

Celi, M., F. Filiciotto, M. Vazzana, V. Arizza, V. Maccarrone, M. Ceraulo, S. Mazzola, and G. Buscaino. (2015). Shipping noise affecting immune responses of European spiny lobster (*Palinurus elephas*). *Canadian Journal of Zoology, 93*, 113–121.

Center for Biological Diversity. (2009). *Petition to List 83 Coral Species under the Endangered Species Act*. San Francisco, CA: Center for Biological Diversity.

Chan, A. A. Y. H., P. Giraldo-Perez, S. Smith, and D. T. Blumstein. (2010a). Anthropogenic noise affects risk assessment and attention: The distracted prey hypothesis. *Biology Letters, 6*(4), 458–461.

Chan, A. A. Y. H., W. D. Stahlman, D. Garlick, C. D. Fast, D. T. Blumstein, and A. P. Blaisdell. (2010b). Increased amplitude and duration of acoustic stimuli enhance distraction. *Animal Behaviour, 80*, 1075–1079.

Chan, I., L. C. Tseng, S. Ka, C. F. Chang, and J. S. Hwang. (2012). An experimental study of the response of the gorgonian coral *Subergorgia suberosa* to polluted seawater from a former coastal mining site in Taiwan. *Zoological Studies, 51*(1), 27–37.

Chappell, S. (2018, August 23, 2018). [Personal commuication to Combs, R. on AFTT Invertebrates Text].

Charifi, M., M. Sow, P. Ciret, S. Benomar, and J. Massabuau. (2017). The sense of hearing in the Pacific oyster, *Magallana gigas*. *PLoS ONE, 12*(10), 19.

Chesapeake Biological Laboratory. (1948). *Effects of Underwater Explosions on Oysters, Crabs and Fish: a Preliminary Report*. (Publication No. 70). Solomons Island, MD: Department of Research and Education.

Cheung, W., J. Alder, V. Karpouzi, R. Watson, V. Lam, C. Day, K. Kaschner, and D. Pauly. (2005) Patterns of Species Richness in the High Seas. *Technical Series no. 20*. Montreal, Canada: Secretariat of the Convention on Biological Diversity.

Chiarelli, R., and M. C. Roccheri. (2014). Marine invertebrates as bioindicators of heavy metal pollution. *Open Journal of Metal, 4*, 93–106.

Christian, J. R., A. Mathieu, D. H. Thomson, D. White, and R. A. Buchanan. (2003). *Effect of Seismic Energy on Snow Crab (Chionoecetes opilio)* (Environmental Research Funds Report). Calgary, Canada: LGL Ltd., Environmental Research Associates.

Chuenpagdee, R., L. E. Morgan, S. M. Maxwell, E. A. Norse, and D. Pauly. (2003). Shifting gears: Addressing the collateral impacts of fishing methods in U.S. waters. *Frontiers in Ecology and the Environment, 1*(10), 517–524.

Clark, H. R., and C. J. Gobler. (2016). Diurnal fluctuations in CO_2 and dissolved oxygen concentrations do not provide a refuge from hypoxia and acidification for early-life-stage bivalves. *Marine Ecology Progress Series, 558*, 1–14.

Clark, R., W. Morrison, M. J. Allen, and L. Claflin. (2005). *Chapter 3: Biogeography of macroinvertebrates* (A Biogeographic Assessment of the Channel Islands National Marine Sanctuary: A Review of Boundary Expansion Concepts for NOAA's National Marine Sanctuary Program). Silver Spring, MD: National Oceanic and Atmospheric Administration, National Centers for Coastal Ocean Science.

Clarke, M. E., C. E. Whitmire, and M. M. Yoklavich. (2015). *State of Deep-Sea Coral and Sponge Ecosystems of the U.S. West Coast: 2015* (Vol. X NOAA Technical Memorandum). Silver Spring, MD: National Oceanic and Atmospheric Administration.

Clements, J. C., K. D. Woodard, and H. L. Hunt. (2016). Porewater acidification alters the burrowing behavior and post-settlement dispersal of juvenile soft-shell clams (*Mya arenaria*). *Journal of Experimental Marine Biology and Ecology, 477*, 103–111.

Cohen, A. L., D. C. McCorkle, S. de Putron, G. A. Gaetani, and K. A. Rose. (2009). Morphological and compositional changes in the skeletons of new coral recruits reared in acidified seawater: Insights into the biomineralization response to ocean acidification. *Geochemistry Geophysics Geosystems, 10*(7), 1–12.

Cole, M., P. Lindeque, E. Fileman, C. Halsband, R. Goodhead, J. Moger, and T. S. Galloway. (2013). Microplastic ingestion by zooplankton. *Environmental Science & Technology, 47*(12), 6646–6655.

Colella, M., R. Ruzicka, J. Kidney, J. Morrison, and V. Brinkhuis. (2012). Cold-water event of January 2010 results in catastrophic benthic mortality on patch reefs in the Florida Keys. *Coral Reefs*, 1–12.

Colin, P. L., and A. C. Arneson. (1995a). Molluscs: Phylum *Mollusca*. In *Tropical Pacific Invertebrates: A Field Guide to the Marine Invertebrates Occurring on Tropical Pacific Coral Reefs, Seagrass Beds and Mangroves* (pp. 157–200). Beverly Hills, CA: Coral Reef Press.

Colin, P. L., and A. C. Arneson. (1995b). Sponges: Phylum *Porifera*. In *Tropical Pacific Invertebrates: A Field Guide to the Marine Invertebrates Occurring on Tropical Pacific Coral Reefs, Seagrass Beds and Mangroves* (pp. 17–62). Beverly Hills, CA: Coral Reef Press.

Cooper, D. A., and P. L. Corcoran. (2010). Effects of mechanical and chemical processes on the degradation of plastic beach debris on the island of Kauai, Hawaii. *Marine Pollution Bulletin, 60*, 650–654.

Cortes, N. J., and M. J. Risk. (1985). A reef under siltation stress: Cahuita, Costa Rica. *Bulletin of Marine Science, 36*(2), 339–356.

Cunning, R., R. Ritson-Williams, and R. D. Gates. (2016). Patterns of bleaching and recovery of Montipora capitata in Kaneohe Bay, Hawaii, USA. *Marine Ecology Progress Series, 551*, 131–139.

Dameron, O. J., M. Parke, M. A. Albins, and R. Brainard. (2007). Marine debris accumulation in the Northwestern Hawaiian Islands: An examination of rates and processes. *Marine Pollution Bulletin 54*, 423–433.

Dasgupta, P. K., P. K. Martinelango, W. A. Jackson, T. A. Anderson, K. Tian, R. W. Tock, and S. Rajagopalan. (2005). The origin of naturally occurring perchlorate: The role of atmospheric processes. *Environmental Science and Technology, 39*(6), 1569–1575.

Davis, A. R., A. Broad, W. Gullett, J. Reveley, C. Steele, and C. Schofield. (2016). Anchors away? The impacts of anchor scour by ocean-going vessels and potential response options. *Marine Policy, 73*, 1–7.

Davis, G. E., P. L. Haaker, and D. V. Richards. (1998). The perilous condition of white abalone, *Haliotis sorenseni*, Bartsch, 1940. *Journal of Shellfish Research, 17*(3), 871–875.

Day, R. D., R. D. McCauley, Q. P. Fitzgibbon, and J. M. Semmens. (2016). Seismic air gun exposure during early-stage embryonic development does not negatively affect spiny lobster *Jasus edwardsii* larvae (Decapoda: Palinuridae). *Scientific Reports, 6*(22723), 9.

De Laubenfels, M. W. (1950). The sponges of Kaneohe Bay, Oahu. *Pacific Science, 4*(1), 3–36.

De Laubenfels, M. W. (1951). The sponges of the Island of Hawaii. *Pacific Science, 5*(3), 256–271.

De Zoysa, M. (2012). Medicinal benefits of marine invertebrates: Sources for discovering natural drug candidates. *Advances in Food and Nutrition Research, 65*, 153–169.

DeMartini, E. E., and J. E. Smith. (2015). Effects of fishing on the fishes and habitat of coral reefs. In C. Mora (Ed.), *Ecology of Fishes on Coral Reefs*. Cambridge, United Kingdom: Cambridge University Press.

Dossot, G. A., J. S. Krumholz, D. M. Hudson, D. L. Pochtar, N. C. Dickenso, E. B. Baker, and T. E. Moll. (2017). *Simulated anthropogenic noise exposure to marine invertebrates using a standing wave tube.* Paper presented at the Acoustical Society of America Meeting. New Orleans, LA.

Downs, C. A., E. Kramarsky-Winter, C. M. Woodley, A. Downs, G. Winters, Y. Loya, and G. K. Ostrander. (2009). Cellular pathology and histopathology of hypo-salinity exposure on the coral *Stylophora pistillata*. *Science of the Total Environment, 407*(17), 4838–4851.

Dubinsky, Z., and I. Berman-Frank. (2001). Uncoupling primary production from population growth in photosynthesizing organisms in aquatic ecosystems. *Aquatic Sciences, 63*, 4–17.

Dugan, J. E., D. M. Hubbard, D. L. Martin, J. M. Engle, D. M. Richards, G. E. Davis, K. D. Lafferty, and R. F. Ambrose. (2000). Macrofauna communities of exposed sandy beaches on the southern California mainland and Channel Islands. In D. R. Browne, K. L. Mitchell, & H. W. Chaney (Eds.), *Proceedings of the Fifth California Islands Symposium, 29 March–1 April 1999 (OCS Study MMS 99-0038)* (pp. 339–346). Santa Barbara, CA: U.S. Department of the Interior, Minerals Management Service.

Dugan, J. E., D. M. Hubbard, K. J. Nielsen, J. Altstatt, and J. Bursek. (2015). *Baseline Characterization of Sandy Beach Ecosystems Along the South Coast of California. Final Report*. La Jolla, CA: University of California San Diego.

Eakin, C. M., G. Liu, A. M. Gomez, J. L. De La Cour, S. F. Heron, W. J. Skirving, E. F. Geiger, K. V. Tirak, and A. E. Strong. (2016). Global Coral Bleaching 2014–2017. *Reef Encounter, 31*, 20–26.

Edmonds, N. J., C. J. Firmin, D. Goldsmith, R. C. Faulkner, and D. T. Wood. (2016). A review of crustacean sensitivity to high amplitude underwater noise: Data needs for effective risk assessment in relation to UK commercial species. *Marine Pollution Bulletin, 108*, 5–11.

Erftemeijer, P. L. A., B. Riegl, B. W. Hoeksema, and P. A. Todd. (2012). Environmental impacts of dredging and other sediment disturbances on corals: A review. *Marine Pollution Bulletin, 64*, 1737–1765.

Etnoyer, P., and L. Morgan. (2003). *Occurrences of Habitat-forming Deep Sea Corals in the Northeast Pacific Ocean: A Report to NOAA's Office of Habitat Conservation*. Redmond, WA: Marine Conservation Biology Institute.

Etnoyer, P., and L. E. Morgan. (2005). Habitat-forming deep-sea corals in the Northeast Pacific Ocean. In A. Freiwald & J. M. Roberts (Eds.), *Cold-water Corals and Ecosystems* (pp. 331–343). Berlin Heidelberg: Springer-Verlag.

Etnoyer, P. J. (2010). Deep-sea corals on seamounts. *Oceanography, 23*(1), 128–129.

Fautin, D., P. Dalton, L. S. Incze, J. Leong, C. Pautzke, A. Rosenberg, P. Sandifer, G. Sedberry, J. W. Tunnell, I. Abbott, R. E. Brainard, M. Brodeur, L. E. Eldredge, M. Feldman, F. Moretzsohn, P. S. Vroom, M. Wainstein, and N. Wolff. (2010). An overview of marine biodiversity in United States waters. *PLoS ONE, 5*(8), e11914.

Fewtrell, J. L., and R. D. McCauley. (2012). Impact of air gun noise on the behaviour of marine fish and squid. *Marine Pollution Bulletin, 64*(5), 984–993.

Filiciotto, F., M. Vazzana, M. Celi, V. Maccarrone, M. Ceraulo, G. Buffa, V. Di Stefano, S. Mazzola, and G. Buscaino. (2014). Behavioural and biochemical stress responses of *Palinurus elephas* after exposure to boat noise pollution in tank. *Marine Pollution Bulletin, 84*(1–2), 104–114.

Filiciotto, F., M. Vazzana, M. Celi, V. Maccarrone, M. Ceraulo, G. Buffa, V. Arizza, G. de Vincenzi, R. Grammauta, S. Mazzola, and G. Buscaino. (2016). Underwater noise from boats: Measurement of its influence on the behaviour and biochemistry of the common prawn (*Palaemon serratus*, Pennant 1777). *Journal of Experimental Marine Biology and Ecology, 478*, 24–33.

Food and Agriculture Organization of the United Nations. (2005). *Fishery Country Profile: United States of America*. Retrieved from ftp://ftp.fao.org/FI/DOCUMENT/fcp/en/FI_CP_US.pdf.

Fossette, S., A. C. Gleiss, J. Chalumeau, T. Bastian, C. D. Armstrong, S. Vandenabeele, M. Karpytchev, and G. C. Hays. (2015). Current-oriented swimming by jellyfish and its role in bloom maintenance. *Current Biology, 25*, 342–347.

Foster, M. S., and D. R. Schiel. (1985). *The Ecology of Giant Kelp Forests in California: A Community Profile*. Moss Landing, CA: U.S. Fish and Wildlife Service.

Foster, T., J. L. Falter, M. T. McCulloch, and P. L. Clode. (2016). Ocean acidification causes structural deformities in juvenile coral skeletons. *Science Advances, 2*(e1501130), 7.

Foster, T., and J. P. Gilmour. (2016). Seeing red: Coral larvae are attracted to healthy-looking reefs. *Marine Ecology Progress Series, 559*, 65–71.

Fox, H. E., and R. L. Caldwell. (2006). Recovery from blast fishing on coral reefs: A tale of two scales. *Ecological Applications, 16*(5), 1631–1635.

Franklin, E. C., P. L. Jokiel, and M. J. Donahue. (2013). Predictive modeling of coral distribution and abundance in the Hawaiian Islands. *Marine Ecology Progress Series, 481*, 121–132.

Freiwald, A., J. H. Fosså, A. Grehan, T. Koslow, and J. M. Roberts. (2004). *Cold-water Coral Reefs: Out of Sight–No Longer Out of Mind*. Cambridge, United Kingdom: United Nations Environmental Program World Conservation Monitoring Center.

Friedlander, A., G. Aeby, S. Balwani, B. Bowen, R. Brainard, A. Clark, J. Kenyon, J. Maragos, C. Meyer, P. Vroom, and J. Zamzow. (2008a). The State of Coral Reef Ecosystems of the Northwestern Hawaiian Islands. In J. E. Waddell & A. M. Clarke (Eds.), *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States* (pp. 263–306). Silver Spring, MD: National Center for Coastal Ocean Science Center for Coastal Monitoring and Assessment's Biogeography Team.

Friedlander, A., G. Aeby, R. Brainard, E. Brown, K. Chaston, A. Clark, P. McGowan, T. Montgomery, W. Walsh, I. Williams, and W. Wiltse. (2008b). The State of Coral Reef Ecosystems of the Main Hawaiian Islands. In J. E. Waddell & A. M. Clarke (Eds.), *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States* (pp. 219–262). Silver Spring, MD: National Center for Coastal Ocean Science Center for Coastal Monitoring and Assessment's Biogeography Team.

Fujii, T. (2012). Climate Change, Sea-level Rise, and Implications for Coastal and Estuarine Shoreline Management with Particular Reference to the Ecology of Intertidal Benthic Macrofauna in Northwest Europe. *Biology 1*, 597–616.

Galloway, S. B., A. W. Bruckner, and C. M. Woodley. (2009). *Coral Health and Disease in the Pacific: Vision for Action*. Silver Spring, MD: National Oceanic and Atmospheric Administration.

Garcia, M. O., J. Caplan-Auerbach, E. H. De Carlo, M. D. Kurz, and N. Becker. (2005). Geology, geochemistry and earthquake history of Loihi Seamount, Hawaii's youngest volcano. *Chemie der Erde-Geochemistry, 66*(2), 81–108.

Gaspin, J. B., G. B. Peters, and M. L. Wisely. (1976). *Experimental Investigations of the Effects of Underwater Explosions on Swimbladder Fish*. Silver Spring, MD: Naval Ordnance Lab.

Gochfeld, D. J. (2004). Predation-induced morphological and behavioral defenses in a hard coral: Implications for foraging behavior of coral-feeding butterflyfishes. *Marine Ecology Progress Series, 267*, 145–158.

Godwin, S., and H. Bolick. (2006). *Inventory of Intertidal and Shallow Subtidal Marine Invertebrates at Kalaupapa National Historical Park Moloka'i, Hawai'i*. Honolulu, HI: National Park Service, Pacific Islands Coral Reef Program.

Goethel, C. L., J. M. Grebmeier, L. W. Cooper, and T. J. Miller. (2017). Implications of ocean acidification in the Pacific Arctic: Experimental responses of three Arctic bivalves to decreased pH and food availability. *Deep-Sea Research Part II: Topical Studies in Oceanography, 144*, 112–124.

Goldstein, M. C., and D. S. Goodwin. (2013). Gooseneck barnacles (*Lepas* spp.) ingest microplastic debris in the North Pacific Subtropical Gyre. *PeerJ, 1*, e184.

Goodall, C., C. Chapman, and D. Neil. (1990). The Acoustic Response Threshold of the Norway Lobster, *Nephrops norvegicus* (L.), in a Free Sound Field. In K. Weise, W. D. Krenz, J. Tautz, H. Reichert, & B. Mulloney (Eds.), *Frontiers in Crustacean Neurobiology* (pp. 106–113). Basel, Switzerland: Birkhauser-Verlag.

Goreau, T. J. (2014). Electrical stimulation greatly increases settlement, growth, survival, and stress resistance of marine organisms. *Natural Resources, 5*, 527–537.

Goulet, T. L., K. P. Shirur, B. D. Ramsby, and R. Iglesias-Prieto. (2017). The effects of elevated seawater temperatures on Caribbean gorgonian corals and their algal symbionts, *Symbiodinium* spp. *PLoS ONE, 12*(2), 21 (e0171032).

Graham, S., J. Bredvik, and B. Saunders. (2014). *Rocky Intertidal Community Monitoring At Naval Auxiliary Landing Field, San Clemente Island, 2013 Annual Report*. San Diego, CA: Naval Facilities Engineering Command (NAVFAC) Southwest, California. Environmental Readiness, Navy Marine Ecology Consortium, Space and Naval Warfare Systems Center Pacific.

Griscom, S. B., and N. S. Fisher. (2004). Bioavailability of Sediment-bound Metals to Marine Bivalve Molluscs: An Overview. *Estuaries, 27*(5), 826–838.

Grizzle, R. E., J. R. Adams, and L. J. Walters. (2002). Historical changes in intertidal oyster (*Crassostrea virginica*) reefs in a Florida lagoon potentially related to boating activities. *Journal of Shellfish Research, 21*(2), 749–756.

Grupe, B. M., M. L. Krach, A. L. Pasulka, J. M. Maloney, L. A. Levin, and C. A. Frieder. (2015). Methane seep ecosystem functions and services from a recently discovered southern California seep. *Marine Ecology, 36 (Supplement 1)*, 91–108.

Guerra, A., A. F. Gonzalez, F. Rocha, J. Gracia, and M. Vecchione. (2004). Calamares gigantes varados. *Investigacion y Ciencia*, 35–37.

Guerra, A., and A. F. Gonzales. (2006). *Severe injuries in the giant squid, Architeuthis dux, stranded after seismic explorations.* Paper presented at the International Workshop: Impacts of seismic survey activities on whales and other marine biota. Dessau, Germany.

Guest, J., M. Heyward, M. Omori, K. Iwao, A. Morse, and C. Boch. (2010). Rearing coral larvae for reef rehabilitation. In A. J. Edwards (Ed.), *Reef Rehabilitation Manual* (pp. 73–98). St. Lucia, Australia: The Coral Reef Targeted Research & Capacity Building for Management Program.

Guest, J. R., J. Low, K. Tun, B. Wilson, C. Ng, D. Raingeard, K. E. Ulstrup, J. T. I. Tanzil, P. A. Todd, T. C. Toh, D. McDougald, L. M. Chou, and P. D. Steinberg. (2016). Coral community response to bleaching on a highly disturbed reef. *Scientific Reports, 6*, 20717.

Gulko, D. (1998). The Corallivores: The crown-of-thorns sea star (*Acanthaster planci*) *Hawaiian Coral Reef Ecology* (pp. 101–102). Honolulu, HI: Mutual Publishing.

Hale, S. S., H. W. Buffum, J. A. Kiddon, and M. M. Hughes. (2017). Subtidal Benthic Invertebrates Shifting Northward Along the US Atlantic Coast. *Estuaries and Coasts, 40*(6), 1744–1756.

Hall, N. M., K. L. E. Berry, L. Rintoul, and M. O. Hoogenboom. (2015). Microplastic ingestion by scleractinian corals. *Marine Biology, 162*, 725–732.

Halpern, B. S., K. L. McLeod, A. A. Rosenberg, and L. B. Crowder. (2008). Managing for cumulative impacts in ecosystem-based management through ocean zoning. *Ocean & Coastal Management, 51*(3), 203–211.

Harter, S. L., M. M. Ribera, A. N. Shepard, and J. K. Reed. (2009). Assessment of fish populations and habitat on Oculina Bank, a deep-sea coral marine protected area off eastern Florida. *Fishery Bulletin, 107*(2), 195–206.

Harvell, C. D., C. E. Mitchell, J. R. Ward, S. Altizer, A. P. Dobson, R. S. Ostfeld, and M. D. Samuel. (2002). Climate warming and disease risks for terrestrial and marine biota. *Science, 296*(5576), 2158–2162.

Hawaii Department of Land and Natural Resources. (1980). *Hawaii Coastal Zone Fisheries Management Study*. Honolulu, HI: Department of Land and Natural Resources, Division of Fish and Game.

Hawaiisfishes. (2017). *Ribbon worms (nemerteans) of Hawaii*. Retrieved from http://www.hawaiisfishes.com/inverts/ribbon_worms/neat_ribbon_worms.htm.

Hawkins, A. D., A. E. Pembroke, and A. N. Popper. (2015). Information gaps in understanding the effects of noise on fishes and invertebrates. *Reviews in Fish Biology and Fisheries, 25*, 39–64.

Hayward, B. W., T. Cedhagen, M. Kaminski, and O. Gross. (2016). *World Foraminifera Database*. Retrieved from http://www.marinespecies.org/foraminifera/.

Heberholz, J., and B. A. Schmitz. (2001). Signaling via water currents in behavioral interactions of snapping shrimp (*Alpheus heterochaelis*). *Biological Bulletin, 201*, 6–16.

Henninger, H. P., and W. H. Watson, III. (2005). Mechanisms underlying the production of carapace vibrations and associated waterborne sounds in the American lobster, *Homarus americanus*. *The Journal of Experimental Biology, 208*, 3421–3429.

Heron, S., J. Morgan, M. Eakin, and W. Skirving. (2008). Chapter 3: Hurricanes and Their Effects on Coral Reefs. In C. Wilkinson & D. Souter (Eds.), *Status of Caribbean Coral Reefs After Bleaching and Hurricanes in 2005* (pp. 31–36). Townsville, Australia: Global Coral Reef Monitoring Network, and Reef and Rainforest Research Centre.

Hewson, I., J. B. Button, B. M. Gudenkauf, B. Miner, A. L. Newton, J. K. Gaydos, J. Wynne, C. L. Groves, G. Hendler, M. Murray, S. Fradkin, M. Breitbart, E. Fahsbender, K. D. Lafferty, A. M. Kilpatrick, C. M. Miner, P. Raimondi, L. Lahner, C. S. Friedman, S. Daniels, M. Haulena, J. Marliave, C. A. Burge, M. E. Eisenlord, and C. D. Harvell. (2014). Densovirus associated with sea-star wasting disease and mass mortality. *Proceedings of the National Academy of Sciences, 111*(28), 17278–17283.

Heyward, A. J., and A. P. Negri. (2012). Turbulence, cleavage, and the naked embryo: A case for coral clones. *Science, 335*, 1064.

Hoadley, K. D., D. T. Pettay, A. G. Grottoli, W.-J. Cai, T. F. Melman, V. Schoepf, X. Hu, Q. Li, H. Xu, Y. Wang, Y. Matsui, J. H. Baumann, and M. E. Warner. (2015). Physiological response to elevated temperature and pCO_2 varies across four Pacific coral species: Understanding the unique host+symbiont response. *Scientific Reports 5:18371*, 1–15.

Hobday, A. J., and M. J. Tegner. (2000). *Status Review of White Abalone (Haliotis sorenseni) throughout its Range in California and Mexico*. Long Beach, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Region Office.

Hobday, A. J., M. J. Tegner, and P. L. Haaker. (2001). Over-exploitation of a broadcast spawning marine invertebrate: Decline of the white abalone. *Reviews in Fish Biology and Fisheries, 10*, 493–514.

Hoover, J. P. (1998a). Echinoderms: Phylum Echinodermata. In *Hawai'i's Sea Creatures: A Guide to Hawai'i's Marine Invertebrates* (pp. 290–335). Honolulu, HI: Mutual Publishing.

Hoover, J. P. (1998b). *Hawaii's Sea Creatures A Guide to Hawaii's Marine Invertebrates*. Korea: Mutual Publishing.

Horton, T. (2016, September 8, 2016). Stealth reefs and the Navy's big guns. *Suffolk News-Herald*.

Hourigan, T. F., P. J. Etnoyer, and S. D. Cairns. (2017a). Introduction to the State of Deep-Sea Coral and Sponge Ecosystems of the United States. In T. F. Hourigan, P. J. Etnoyer, & S. D. Cairns (Eds.), *The*

State of Deep-Sea Coral and Sponge Ecosystems of the United States (Vol. National Oceanic and Atmospheric Administration Technical Memorandum NMFS-OHC-3, pp. 1–34). Silver Spring, MD: National Oceanic and Atmospheric Administration.

Hourigan, T. F., J. Reed, S. Pomponi, S. W. Ross, A. W. David, and S. Harter. (2017b). State of the Deep-Sea Coral and Sponge Ecosystems off the Southeast United States *The State of Deep-Sea Coral and Sponge Ecosystems in the United States* (pp. 13-11–13-61). Silver Spring, MD: National Oceanic and Atmospheric Administration.

Hu, M. Y., H. Y. Yan, W. S. Chung, J. C. Shiao, and P. P. Hwang. (2009). Acoustically evoked potentials in two cephalopods inferred using the auditory brainstem response (ABR) approach. *Comparative Biochemistry and Physiology, Part A, 153*, 278–283.

Hughes, A. R., D. A. Mann, and D. L. Kimbro. (2014). Predatory fish sounds can alter crab foraging behavior and influence bivalve abundance. *Proceedings of the Royal Society Biological Sciences, 281*(20140715).

Hughes, T. P., and J. H. Connell. (1999). Multiple stressors on coral reefs: A long-term perspective. *Limnology and Oceanography, 44*(3, part 2), 932–940.

Hughes, T. P., A. H. Baird, D. R. Bellwood, M. Card, S. R. Connolly, C. Folke, R. Grosberg, O. Hoegh-Guldberg, J. B. C. Jackson, J. Kleypas, J. M. Lough, P. A. Marshall, M. Nystrom, S. R. Palumbi, J. M. Pandolfi, B. Rosen, and J. Roughgarden. (2003). Climate change, human impacts, and the resilience of coral reefs. *Science, 301*(5635), 929–933.

Jackson, J. B. C., M. X. Kirby, W. H. Berger, K. A. Bjorndal, L. W. Botsford, B. J. Bourque, R. H. Bradbury, R. Cooke, J. M. Erlandson, J. A. Estes, T. P. Hughes, S. Kidwell, C. B. Lange, H. S. Lenihan, J. M. Pandolfi, C. H. Peterson, R. S. Steneck, M. J. Tegner, and R. R. Warner. (2001). Historical overfishing and the recent collapse of coastal ecosystems. *Science, 293*, 629–638.

Jeffs, A., N. Tolimieri, and J. C. Montgomery. (2003). Crabs on cue for the coast: The use of underwater sound for orientation by pelagic crab stages. *Marine Freshwater Resources, 54*, 841–845.

Jennings, S., and M. J. Kaiser. (1998). The effects of fishing on marine ecosystems. In J. H. S. Blaxter, A. J. Southward, & P. A. Tyler (Eds.), *Advances in Marine Biology* (Vol. 34, pp. 201–352). Warwick, United Kingdom: Academic Press.

Jokiel, P. L., and E. K. Borwn. (2004). Global warming, regional trends and inshore environmental conditions influence coral bleaching in Hawaii. *Global Change Biology, 10*, 1627–1641.

Jokiel, P. L. (2008). Biology and Ecological Functioning of Coral Reefs in the Main Hawaiian Islands. In B. Riegl & R. E. Dodge (Eds.), *Coral Reefs of the USA*. Berlin, Germany: Springer Science.

Jompa, J., Suharto, E. M. Anpusyahnur, P. N. Dwjja, J. Subagio, I. Alimin, R. Anwar, S. Syamsuddin, T. Heni, U. Radiman, H. Triyono, R. A. Sue, and N. Soeyasa. (2012). Electrically Stimulated Corals in Indonesia Reef Restoration Projects Show Greatly Accelerated Growth Rates. In T. J. Goreau & R. K. T. Trench (Eds.), *Innovative Methods of Marine Ecosystem Restoration* (pp. 47–58). Boca Raton, FL: CRC Press.

Jumars, P. A., K. M. Dorgan, and S. M. Lindsay. (2015). Diet of worms emended: An update of polychaete feeding guilds. *Annual Review of Marine Science, 7*, 497–520.

Kahng, S. E., and J. E. Maragos. (2006). The deepest, zooxanthellate scleractinian corals in the world? *Coral Reefs, 25*, 254.

Kaifu, K., T. Akamatsu, and S. Segawa. (2008). Underwater sound detection by cephalopod statocyst. *Fisheries Science, 74*, 781–786.

Kaiser, M. J., J. S. Collie, S. J. Hall, S. Jennings, and I. R. Poiner. (2002). Modification of marine habitats by trawling activities: Prognosis and solutions. *Fish and Fisheries, 3*(2), 114–136.

Kaplan, M. B., and T. A. Mooney. (2016). Coral reef soundscapes may not be detectable far from the reef. *Scientific Reports, 6*(31862), 1–10.

Kaplanis, N. J., J. Harris, and J. Smith. (2016). Distribution patterns of the non-native seaweeds *Sargassum horneri* (Turner) C. Agardh and *Undaria pinnatifida* (Harvey) Suringar on the San Diego and Pacific coast of North America. *Aquatic Invasions, 11*(2), 111–124.

Kaposi, K. L., B. Mos, B. P. Kelaher, and S. A. Dworjanyn. (2014). Ingestion of microplastic has limited impact on a marine larva. *Environmental Science & Technology, 48*(3), 1638–1645.

Karleskint, G., Jr., R. Turner, and J. W. Small, Jr. (2006). *Introduction to Marine Biology* (2nd ed.). Belmont, CA: Thomson Brooks/Cole.

Karlsson, S., and A. C. Albertsson. (1998). Biodegradable polymers and environmental interaction. *Polymer Engineering and Science, 38*(8), 1251–1253.

Keevin, T. M., and G. L. Hempen. (1997). *The Environmental Effects of Underwater Explosions with Methods to Mitigate Impacts*. St. Louis, MO: U.S. Army Corps of Engineers.

Keller, A. A., E. L. Fruh, M. M. Johnson, V. Simon, and C. McGourty. (2010). Distribution and abundance of anthropogenic marine debris along the shelf and slope of the U.S. West Coast. *Marine Pollution Bulletin, 60*(5), 692–700.

Kelley, C., G. Carton, M. Tomlinson, and A. Gleason. (2016). Analysis of towed camera images to determine the effects of disposed mustard-filled bombs on the deep water benthic community off south Oahu. *Deep Sea Research Part II: Topical Studies in Oceanography, 128*, 34–42.

Kershaw, P., S. Katsuhiko, S. Lee, J. Samseth, and D. Woodring. (2011). Plastic Debris in the Ocean. In T. Goverse & S. Bech (Eds.), *United Nations Environment Programme Yearbook 2011: Emerging Issues in our Global Environment*. Nairobi, Kenya: United Nations Environment Programme.

Kirstein, I. V., S. Kirmizi, A. Wichels, A. Garin-Fernandez, R. Erler, M. Loder, and G. Gerdts. (2016). Dangerous hitchhikers? Evidence for potentially pathogenic *Vibrio spp*. on microplastic particles. *Marine Environmental Research, 120*, 1–8.

Koehl, M. A. R., J. R. Koseff, J. P. Crimaldi, M. G. McCay, T. Cooper, M. B. Wiley, and P. A. Moore. (2001). Lobster sniffing: Antennule design and hydrodynamic filtering of information in an odor plume. *Science, 294*, 1948–1951.

Koide, S., J. A. K. Silva, V. Dupra, and M. Edwards. (2016). Bioaccumulation of chemical warfare agents, energetic materials, and metals in deep-sea shrimp from discarded military munitions sites off Pearl Harbor. *Deep Sea Research Part II: Topical Studies in Oceanography, 128*, 53–62.

Kunc, H. P., G. N. Lyons, J. D. Sigwart, K. E. McLaughlin, and J. D. R. Houghton. (2014). Anthropogenic noise affects behavior across sensory modalities. *The American Naturalist, 184*(4), 1–9.

Kunc, H. P., K. E. McLaughlin, and R. Schmidt. (2016). Aquatic noise pollution: Implications for individuals, populations, and ecosystems. *Proceedings of the Royal Society of London B, 283*(20160839), 1–8.

Lagardère, J. P. (1982). Effects of noise on growth and reproduction of *Crangon crangon* in rearing tanks. *Marine Biology, 71*, 177–185.

Latha, G., S. Senthilvadivu, R. Venkatesan, and V. Rajendran. (2005). Sound of shallow and deep water lobsters: Measurements, analysis, and characterization. *The Journal of the Acoustical Society of America, 117*(5), 2720–2723.

Leal, M. C., J. Puga, J. Serodio, N. C. Gomes, and R. Calado. (2012). Trends in the discovery of new marine natural products from invertebrates over the last two decades – where and what are we bioprospecting? *PLoS ONE, 7*(1), e30580.

Leite, L., D. Campbell, L. Versiani, J. Anchieta, C. C. Nunes, and T. Thiele. (2016). First report of a dead giant squid (*Architeuthis dux*) from an operating seismic vessel. *Marine Biodiversity Records, 9*(26), 1–3.

Levinton, J. S. (2009). *Marine Biology: Function, Biodiversity, Ecology* (3rd ed.). New York, NY: Oxford University Press.

Lillis, A., D. B. Eggleston, and D. R. Bohnenstiehl. (2013). Oyster larvae settle in response to habitat-associated underwater sounds. *PLoS ONE, 8*(10), e79337.

Lillis, A., D. Bohnenstiehl, J. W. Peters, and D. Eggleston. (2016). Variation in habitat soundscape characteristics influences settlement of a reef-building coral. *PeerJ, 4:e2557*.

Lindholm, J., M. Gleason, D. Kline, L. Clary, S. Rienecke, and M. Bell. (2013). *Central Coast Trawl Impact and Recovery Study: 2009–2012 Final Report*. Sacramento, CA: California Ocean Protection Council.

Lirman, D., S. Schopmeyer, D. Manzello, L. J. Gramer, W. F. Precht, F. Muller-Karger, K. Banks, B. Barnes, E. Bartels, A. Bourque, J. Byrne, S. Donahue, J. Duquesnel, L. Fisher, D. Gilliam, J. Hendee, M. Johnson, K. Maxwell, E. McDevitt, J. Monty, D. Rueda, R. Ruzicka, and S. Thanner. (2011). Severe 2010 cold-water event caused unprecedented mortality to corals of the Florida reef tract and reversed previous survivorship patterns. *PLoS ONE, 6*(8), e23047.

Lobel, L. K., and P. Lobel. (2000). *Coral Reef Protection Implementation Plan*. Washington, DC: U.S. Department of Defense, U.S. Department of the Navy, U.S. Coral Reef Task Force.

Lohmann, K. J., N. D. Pentcheff, G. A. Nevitt, G. D. Stetten, R. K. Zimmer-Faust, H. E. Jarrard, and L. C. Boles. (1995). Magnetic orientation of spiny lobsters in the ocean: Experiments with undersea coil systems. *The Journal of Experimental Biology, 198*(10), 2041–2048.

Lohmann, K. J., and C. M. F. Lohmann. (2006). Sea turtles, lobsters, and oceanic magnetic maps. *Marine and Freshwater Behaviour and Physiology, 39*(1), 49–64.

Lotufo, G. R., G. Rosen, W. Wild, and G. Carton. (2013). *Summary Review of the Aquatic Toxicology of Munitions Constituents*. (ERDC/EL TR-13-8). Washington, DC: U.S. Army Corps of Engineers.

Lough, J. M., and M. J. H. van Oppen. (2009). Coral Bleaching: Patterns, Processes, Causes and Consequences. In M. J. H. van Oppen & J. M. Lough (Eds.), *Coral Bleaching* (Vol. Ecological Studies 205). Berlin, Germany: Springer-Verlag.

Love, M. S., M. M. Yoklavich, B. A. Black, and A. H. Andrews. (2007). Age of black coral (*Antipathes dendrochristos*) colonies, with notes on associated invertebrate species. *Bulletin of Marine Science, 80*(2), 391–400.

Love, M. S., M. M. Nishimoto, S. Clark, and A. S. Bull. (2016). *Renewable Energy in situ Power Cable Observation*. (OCS Study 2016-008). Camarillo, CA: U.S. Department of the Interior, Bureau of Ocean Energy Management, Pacific OCS Region.

Lovell, J. M., M. M. Findlay, R. M. Moate, and H. Y. Yan. (2005). The hearing abilities of the prawn, *Palaemon serratus*. *Comparative Biochemistry and Physiology, Part A, 140*, 89–100.

Lovell, J. M., R. M. Moate, L. Christiansen, and M. M. Findlay. (2006). The relationship between body size and evoked potentials from the statocysts of the prawn, *Palaemon serratus*. *The Journal of Experimental Biology, 209*, 2480–2485.

Lumsden, S. E., T. F. Hourigan, A. W. Bruckner, and G. Dorr. (2007). *The State of Deep Coral Ecosystems of the United States: 2007*. (NOAA Technical Memorandum CRCP-3). Silver Spring, MD: National Oceanic and Atmospheric Administration.

Lunden, J. J., C. G. McNicholl, C. R. Sears, C. L. Morrison, and E. E. Cordes. (2014). Acute survivorship of the deep-sea coral *Lophelia pertusa* from the Gulf of Mexico under acidification, warming, and deoxygenation. *Frontiers in Marine Science, 1*(78).

Mackie, G. O., and C. L. Singla. (2003). The capsular organ of *Chelyosoma productum* (Ascidiacea: Corellidae): A new tunicate hydrodynamic sense organ. *Brain, Behavior and Evolution, 61*, 45–58.

Macpherson, E. (2002). Large-scale species-richness gradients in the Atlantic Ocean. *Proceedings of the Royal Society of Biology, 269*(1501), 1715–1720.

Macreadie, P. I., A. M. Fowler, and D. J. Booth. (2011). Rigs-to-reefs: Will the deep sea benefit from artificial habitat? *Frontiers in Ecology and the Environment, 9*(8), 455–461.

Mah, C. L., and D. B. Blake. (2012). Global diversity and phylogeny of the Asteroidea (Echinodermata). *PLoS ONE, 7*(4), e35644.

Maragos, J. E., D. C. Potts, G. Aeby, D. Gulko, J. Kenyon, D. Siciliano, and D. VanRavenswaay. (2004). 2000–2002 Rapid ecological assessment of corals (Anthozoa) on shallow reefs of the northwestern Hawaiian Islands. Part 1: Species and distribution. *Pacific Science, 58*(2), 211–230.

Marks, L. M., P. Salinas-Ruiz, D. C. Reed, S. J. Holbrook, C. S. Culver, J. M. Engle, G. J. Kushner, J. E. Caselle, J. Freiwald, J. P. Williams, J. R. Smith, L. E. Aguilar-Rosas, and N. J. Kaplanis. (2015). Range expansion of a non-native, invasive macroalga *Sargassum horneri* (Turner) C. Agardh, 1820 in the eastern Pacific. *BioInvasions Records, 4*(4), 243–248.

McCauley, R. D., J. Fewtrell, A. J. Duncan, C. Jenner, M.-N. Jenner, J. D. Penrose, R. I. T. Prince, A. Adhitya, J. Murdoch, and K. A. McCabe. (2000). *Marine Seismic Surveys: Analysis and Propagation of Air-gun Signals; and Effects of Air-gun Exposure on Humpback Whales, Sea Turtles, Fishes and Squid*. Bentley, Australia: Centre for Marine Science and Technology.

McCauley, R. D., R. D. Day, K. M. Swadling, Q. P. Fitzgibbon, R. A. Watson, and J. M. Semmens. (2017). Widely used marine seismic survey air gun operations negatively impact zooplankton. *Nature, 1*(0195).

McClanahan, T. R., S. D. Donner, J. A. Maynard, M. A. MacNeil, N. A. Graham, J. Maina, A. C. Baker, I. J. Alemu, M. Beger, S. J. Campbell, E. S. Darling, C. M. Eakin, S. F. Heron, S. D. Jupiter, C. J. Lundquist, E. McLeod, P. J. Mumby, M. J. Paddack, E. R. Selig, and R. van Woesik. (2012). Prioritizing key resilience indicators to support coral reef management in a changing climate. *PLoS ONE, 7*(8), e42884.

McClanahan, T. R. (2017). Changes in coral sensitivity to thermal anomalies. *Marine Ecology Progress Series, 570*, 71–85.

McDermott, J. J. (2001). Status of the Nemertea as prey in marine ecosystems. *Hydrobiologia, 456*(1), 7–20.

McMurray, S., J. Vicente, K. Jabanoski, and T. Lewis. (2012). Spawning of the basket star, *Astrophyton muricatum,* in the Bahamas. *Coral Reefs, 1*, 1.

Mead, K. S., and M. W. Denny. (1995). The effects of hydrodynamic shear stress on fertilization and early development of the purple sea urchin *Strongylocentrotus purpuratus*. *The Biological Bulletin, 188*, 46–56.

Mearns, A. J., D. J. Reish, P. S. Oshida, T. Ginn, and M. A. Rempel-Hester. (2011). Effects of Pollution on Marine Organisms. *Water Environment Research, 83*(10), 1789–1852.

Miller, K. J., A. A. Rowden, A. Williams, and V. Häussermann. (2011). Out of their depth? Isolated deep populations of the cosmopolitan coral *Desmophyllum dianthus* may be highly vulnerable to environmental change. *PLoS ONE, 6*(5), e19004.

Miloslavich, P., E. Klein, J. M. Díaz, C. E. Hernández, G. Bigatti, L. Campos, F. Artigas, J. Castillo, P. E. Penchaszadeh, P. E. Neill, A. Carranza, M. V. Retana, J. M. Díaz de Astarloa, M. Lewis, P. Yorio, M. L. Piriz, D. Rodríguez, Y. Yoneshigue-Valentin, L. Gamboa, and A. Martín. (2011). Marine Biodiversity in the Atlantic and Pacific Coasts of South America: Knowledge and Gaps. *PLoS ONE, 6*(1), e14631.

Miner, C. M., J. L. Burnaford, R. F. Ambrose, L. Antrim, H. Bohlmann, C. A. Blanchette, J. M. Engle, S. C. Fradkin, R. Gaddam, C. D. G. Harley, B. G. Miner, S. N. Murray, J. R. Smith, S. G. Whitaker, and P. T. Raimondi. (2018). Large-scale impacts of sea star wasting disease (SSWD) on intertidal sea stars and implications for recovery. *PLoS ONE, 13*(3), e0192870.

Minton, D., and M. Carnevale. (2006). *A Preliminary Survey of the Marine and Intertidal Invertebrates of Kalaupapa National Historical Park*. Molokai, HI: National Park Service Report submitted to Kalaupapa National Historical Park, Natural Resources Division.

Mintz, J. D. (2012). *Vessel Traffic in the Hawaii-Southern California and Atlantic Fleet Testing and Training Study Areas*. (CRM D0026186.A2/Final). Alexandria, VA: Center for Naval Analyses.

Montgomery, J. C., A. Jeffs, S. D. Simpson, M. Meekan, and C. Tindle. (2006). Sound as an orientation cue for the pelagic larvae of reef fishes and decapod crustaceans. *Advances in Marine Biology, 51*, 143–196.

Mooney, T. A., R. T. Hanlon, J. Christensen-Dalsgaard, P. T. Madsen, D. Ketten, and P. E. Nachtigall. (2010). Sound detection by the longfin squid (*Loligo pealeii*) studied with auditory evoked potentials: Sensitivity to low-frequency particle motion and not pressure. *The Journal of Experimental Biology, 213*, 3748–3759.

Moore, S., M. Sutula, T. Von Bitner, G. Lattin, and K. Schiff. (2016). *Southern California Bight 2013 Regional Monitoring Program: Volume III. Trash and Marine Debris*. (Technical Report 928). Costa Mesa, CA: Southern California Coastal Water Research Project.

Mora, C., D. P. Tittensor, S. Adl, A. G. Simpson, and B. Worm. (2011). How many species are there on Earth and in the ocean? *PLoS Biology, 9*(8), 1–8.

Muller, E. M., N. M. Leporacci, K. J. Macartney, A. G. Shea, R. E. Crane, E. R. Hall, and K. B. Ritchie. (2017). Low pH reduces the virulence of black band disease on *Orbicella faveolata*. *PLoS ONE, 12*(6).

Murray, F., S. Hennige, J. M. Roberts, E. Anagnostou, A. Gori, L. Wicks, J. Stewart, and G. Foster. (2016). *Cold-water-corals in a high CO_2 ocean: Behaviour, physiology and growth in Desmophyllum dianthus*. Paper presented at the Annual Science Meeting. University of Strathclyde, Glasgow, Scotland.

Muthukrishnan, R., and P. Fong. (2014). Multiple anthropogenic stressors exert complex, interactive effects on a coral reef community. *Coral Reefs, 33*, 911–921.

Myrberg, A. A., Jr. (2001). The acoustical biology of elasmobranchs. *Environmental Biology of Fishes, 60*, 31–45.

Nakamachi, T., H. Ishida, and N. Hirohashi. (2015). Sound production in the aquatic isopod *Cymodoce japonica* (Crustacea: Peracarida). *The Biological Bulletin, 229*(2), 167–172.

National Marine Fisheries Service, and Southwest Regional Office. (2008). *White Abalone Recovery Plan (Haliotis sorenseni)*. Long Beach, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

National Ocean and Atmospheric Administration. (2016). *Deep-Sea Coral Ecosystems*. Retrieved from https://www.fisheries.noaa.gov/national/habitat-conservation/deep-sea-coral-habitat.

National Ocean Service. (2016a). *What is coral bleaching?* Retrieved from http://oceanservice.noaa.gov/facts/coral_bleach.html.

National Ocean Service. (2016b). *Where Are Reef Building Corals Found*. Retrieved from http://oceanservice.noaa.gov/education/tutorial_corals/coral05_distribution.html.

National Oceanic and Atmospheric Administration. (2008a). *Corals: Anthropogenic Threats to Corals*. Retrieved from http://oceanservice.noaa.gov/education/kits/corals/coral09_humanthreats.html.

National Oceanic and Atmospheric Administration. (2008b). *Corals: Natural Threats to Coral Reefs*. Retrieved from http://oceanservice.noaa.gov/education/kits/corals/coral08_naturalthreats.html.

National Oceanic and Atmospheric Administration, and National Marine Fisheries Service. (2008). *Habitat Connections: Deep Sea Corals*. Washington, DC: U.S. Department of Commerce.

National Oceanic and Atmospheric Administration. (2015). *NOAA declares third ever global coral bleaching event*. Retrieved from http://www.noaanews.noaa.gov/stories2015/100815-noaa-declares-third-ever-global-coral-bleaching-event.html.

National Oceanic and Atmospheric Administration, and NOAA's Coral Reef Conservation Program. (2016). *Coral Facts*. Retrieved from http://coralreef.noaa.gov/education/coralfacts.html.

National Oceanic and Atmospheric Administration. (2018). *White Abalone (Haliotis sorenseni)*. Retrieved from https://www.fisheries.noaa.gov/species/white-abalone.

National Oceanic and Atmospheric Administration Fisheries, and Southwest Fisheries Science Center. (2010). *Deep sea coral communities and fisheries habitats off California*. Retrieved from https://swfsc.noaa.gov/textblock.aspx?Division=FED&ParentMenuId=54&id=16614.

National Oceanic and Atmospheric Administration Fisheries. (2015). *Invertebrates and Plants. Office of Protected Resources*. Retrieved from http://www.nmfs.noaa.gov/pr/species/invertebrates/.

National Oceanic and Atmospheric Administration Fisheries. (2018). *Black Abalone (Haliotis cracherodii)*. Retrieved from https://www.st.nmfs.noaa.gov/ecosystems/lme/index.

National Oceanic and Atmospheric Administration Marine Debris Program. (2014a). *Report on the Occurrence of Health Effects of Anthropogenic Debris Ingested by Marine Organisms*. Silver Spring, MD: National Ocean Service.

National Oceanic and Atmospheric Administration Marine Debris Program. (2014b). *Report on the Entanglement of Marine Species in Marine Debris with an Emphasis on Species in the United States*. Silver Spring, MD: National Oceanic and Atmospheric Administration.

Navy Currents Magazine. (2011). SSC Pacific Farm Helps Restore Southern California Abalone Populations. *Currents, Fall 2011,* 48–50.

Nedelec, S. L., A. N. Radford, S. D. Simpson, B. Nedelec, D. Lecchini, and S. C. Mills. (2014). Anthropogenic noise playback impairs embryonic development and increases mortality in a marine invertebrate. *Scientific Reports, 4*(5891), 1–4.

Negri, A. P., L. D. Smith, N. S. Webster, and A. J. Heyward. (2002). Understanding ship-grounding impacts on a coral reef: Potential effects of anti-foulant paint contamination on coral recruitment. *Marine Pollution Bulletin, 44*, 111–117.

Neuman, M., B. Tissot, and G. VanBlaricom. (2010). Overall status and threats assessment of black abalone (*Haliotis cracherodii* Leach, 1814) populations in California. *Journal of Shellfish Research 29*(3), 577–586.

Normandeau Associates, Inc. (2012). *Effects of Noise on Fish, Fisheries, and Invertebrates in the U.S. Atlantic and Arctic from Energy Industry Sound-Generating Activities*. Bedford, NH: United States Department of the Interior.

Norstrom, A. V., M. Nystrom, J. Lokrantz, and C. Folke. (2009). Alternative states on coral reefs: Beyond coral-macroalgal phase shifts. *Marine Ecology Progress Series, 376*, 293–306.

Nybakken, J. W. (1993). *Marine Biology, an Ecological Approach* (3rd ed.). New York, NY: Harper Collins College Publishers.

Ocean Conservancy. (2010). *Trash Travels: From Our Hands to the Sea, Around the Globe, and Through Time* (International Coastal Cleanup Report). Washington, DC: Ocean Conservancy.

Pacific Islands Fisheries Science Center. (2014). *Reefs for the future: Resilience of coral reefs in the main Hawaiian Islands*. (SP-15-001). Honolulu, HI: National Oceanic and Atmospheric Administration Fisheries Pacific Science Center, Pacific Islands Fisheries Science Center Special Publication.

Packard, A., H. E. Karlsen, and O. Sand. (1990). Low frequency hearing in cephalopods. *Journal of Comparative Physiology A, 166*, 501–505.

Packer, D. B., M. S. Nizinski, M. S. Bachman, A. F. Drohan, M. Poti, and B. P. Kinlan. (2017). State of the Deep-Sea Coral and Sponge Ecosystems off the Northeast United States. In T. F. Hourigan, P. J. Etnoyer, & S. D. Cairns (Eds.), *The State of Deep-Sea Coral and Sponge Ecosystems in the United States* (Vol. NOAA Technical Memorandum NMFS-OHC-X, pp. 9–1–9–65). Silver Spring, MD: National Oceanic and Atmospheric Administration.

Pait, A. S., A. L. Mason, D. R. Whitall, J. D. Christensen, and S. I. Hartwell. (2010). Chapter 5: Assessment of Chemical Contaminants in Sediments and Corals in Vieques. In L. J. Bauer & M. S. Kendall (Eds.), *An Ecological Characterization of the Marine Resources of Vieques, Puerto Rico* (pp. 101–150). Silver Spring, MD: National Oceanic and Atmospheric Administration.

Pandolfi, J. M., R. H. Bradbury, E. Sala, T. P. Hughes, K. A. Bjorndal, R. G. Cooke, D. McArdle, L. McClenachan, M. J. H. Newman, G. Paredes, R. R. Warner, and J. B. C. Jackson. (2003). Global trajectories of the long-term decline of coral reef ecosystems. *Science, 301*, 955–958.

Pansch, C., G. S. I. Hattich, M. E. Heinrichs, A. Pansch, Z. Zagrodzka, and J. N. Havenhand. (2018). Long-term exposure to acidification disrupts reproduction in a marine invertebrate. *PLoS ONE, 13*(2), e0192036.

Parrish, F. A., and A. R. Baco. (2007). State of Deep Coral Ecosystems in the U.S. Pacific Islands Region: Hawaii and the U.S. Pacific Territories. In S. E. Lumsden, T. F. Hourigan, A. Bruckner, & D. G. Wand (Eds.), *The State of Deep Coral Ecosystems of the United States* (Vol. NOAA Technical Memorandum CRCP-3, pp. 155–194). Silver Spring, MD: National Oceanic and Atmospheric Administration.

Parrish, F. A., A. R. Baco, C. Kelley, and H. Reiswig. (2015). State of Deep-Sea Coral and Sponge Ecosystems of the U.S. Pacific Islands Region: 2015. In T. F. Hourigan, P. J. Etnoyer, & S. D. Cairns (Eds.), *The State of Deep-Sea Coral and Sponge Ecosystems of the United States: 2015* (pp. 38). Silver Spring, MD: National Oceanic and Atmospheric Administration.

Parry, G. D., and A. Gason. (2006). The effect of seismic surveys on catch rates of rock lobsters in western Victoria, Australia. *Fisheries Research, 79*, 272–284.

Patek, S. N., and R. L. Caldwell. (2006). The stomatopod rumble: Low frequency sound production in *Hemisquilla californiensis*. *Marine and Freshwater Behaviour and Physiology, 39*(2), 99–111.

Patek, S. N., L. E. Shipp, and E. R. Staaterman. (2009). The acoustics and acoustic behavior of the California spiny lobster (*Panulirus interruptus*). *The Journal of the Acoustical Society of America, 125*(5), 3434–3443.

Paull, C. K., W. R. Normark, W. Ussler, III, D. W. Caress, and R. Keaten. (2008). Association among active seafloor deformation, mound formation, and gas hydrate growth and accumulation within the seafloor of the Santa Monica Basin, offshore California. *Marine Geology, 250*(3–4), 258–275.

Pauly, D., V. Christensen, S. Guenette, T. J. Pitcher, U. R. Sumaila, C. J. Walters, R. Watson, and D. Zeller. (2002). Towards sustainability in world fisheries. *Nature, 418*(6898), 689–695.

Payne, J. F., C. A. Andrews, L. L. Fancey, A. L. Cook, and J. R. Christian. (2007). *Pilot Study on the Effects of Seismic Air Gun Noise on Lobster (Homarus americanus)*. St. John's, NL Environmental Studies Research Funds Report

Pearse, V., J. Pearse, M. Buchsbaum, and R. Buchsbaum. (1987). *Living Invertebrates*. Palo Alto, CA: Boxwood Press.

Pearson, W. H., J. R. Skalski, S. D. Sulkin, and C. I. Malme. (1994). Effects of seismic energy releases on the survival and development of zoeal larvae of dungeness crab (*Cancer magister*). *Marine Environmental Research, 38*, 93–113.

Peng, C., X. Zhao, S. Liu, W. Shi, Y. Han, C. Guo, J. Jiang, H. Wan, T. Shen, and G. Liu. (2016). Effects of anthropogenic sound on digging behavior, metabolism, Ca^{2+}/Mg^{2+} ATPase activity, and metabolism-related gene expression of the bivalve *Sinonovacula constricta*. *Scientific Reports, 6*(24266), 12.

Perea-Blázquez, A., S. K. Davy, and J. J. Bell. (2012). Estimates of particulate organic carbon flowing from the pelagic environment to the benthos through sponge assemblages. *PLoS ONE, 7*(1), e29569.

Perkol-Finkel, S., N. Shashar, and Y. Benayahu. (2006). Can artificial reefs mimic natural reef communities? The roles of structural features and age. *Marine Environmental Research, 61*, 121–135.

Pine, M. K., A. J. Jeffs, and C. A. Radford. (2016). Effects of Underwater Turbine Noise on Crab Larval Metamorphosis. In A. Popper & A. Hawkins (Eds.), *The Effects of Noise on Aquatic Life II. Advances in Experimental Medicine and Biology* (Vol. 875, pp. 847–852). New York, NY: Springer.

Polese, G., C. Bertapelle, and A. Cosmo. (2015). Role of olfaction in *Octopus vulgaris* reproduction. *General and Comparative Endocrinology, 210*, 55–62.

Polovina, J. J., P. Kleiber, and D. R. Kobayashi. (1999). Application of TOPEX-POSEIDON satellite altimetry to simulate transport dynamics of larvae of spiny lobster, *Panulirus marginatus*, in the Northwestern Hawaiian Islands, 1993–1996. *Fishery Bulletin, 97*, 132–143.

Popper, A. N., M. Salmon, and K. W. Horch. (2001). Acoustic detection and communication by decapod crustaceans. *Journal of Comparative Physiology A, 187*, 83–89.

Porter, J. W., P. Dustan, W. C. Jaap, K. L. Patterson, V. Kosmynin, O. W. Meier, M. E. Patterson, and M. Parsons. (2001). Patterns of spread of coral disease in the Florida Keys. *Hydrobiologia, 460*, 1–24.

Posey, M., and T. Alphin. (2002). Resilience and Stability in an Offshore Benthic Community: Responses to Sediment Borrow Activities and Hurricane Disturbance. *Journal of Coastal Research, 18*(4), 685–697.

Precht, W. F., R. B. Aronson, and D. W. Swanson. (2001). Improving scientific decision-making in the restoration of ship-grounding sites on coral reefs. *Bulletin of Marine Science, 69*(2), 1001–1012.

Putnam, H. M., and R. D. Gates. (2015). Preconditioning in the reef-building coral *Pocillopora damicornis* and the potential for trans-generational acclimatization in coral larvae under future climate change conditions. *The Journal of Experimental Biology, 218*, 2365–2372.

Quattrini, A. M., M. S. Nizinski, J. D. Chaytor, A. W. Demopoulos, E. B. Roark, S. C. France, J. A. Moore, T. Heyl, P. J. Auster, B. Kinlan, C. Ruppel, K. P. Elliott, B. R. Kennedy, E. Lobecker, A. Skarke, and T. M. Shank. (2015). Exploration of the Canyon-Incised Continental Margin of the Northeastern United States Reveals Dynamic Habitats and Diverse Communities. *PLoS ONE, 10*(10), 1–32.

Radford, C. A., A. G. Jeffs, and J. C. Montgomery. (2007). Directional swimming behavior by five species of crab postlarvae in response to reef sound. *Bulletin of Marine Science, 2*(80), 369–378.

Radford, C. A., J. A. Stanley, C. T. Tindle, J. C. Montgomery, and A. G. Jeffs. (2010). Localised coastal habitats have distinct underwater sound signatures. *Marine Ecology Progress Series, 401*, 21–29.

Radjasa, O. K., Y. M. Vaske, G. Navarro, H. C. Vervoort, K. Tenney, R. G. Linington, and P. Crews. (2011). Highlights of marine invertebrate-derived biosynthetic products: Their biomedical potential and possible production by microbial associants. *Bioorganic and Medicinal Chemistry, 19*(22), 6658 – 6674.

Raimondi, P., D. Orr, N. Fletcher, M. Redfield, D. Lohse, M. Miner, M. George, R. Gaddam, J. Engle, S. Lee, and S. Whitaker. (2012). *Estimation of population size of the black abalone, Haliotis cracherodii, on San Clemente Island*. Santa Cruz, CA: Department of Ecology and Evolutionary Biology; Long Marine Laboratory.

Ravera, S., C. Falugi, D. Calzia, I. M. Pepe, I. Panfoli, and A. Morelli. (2006). First cell cycles of sea urchin Paracentrotus lividus are dramatically impaired by exposure to extremely low-frequency electromagnetic field. *Biology of Reproduction, 75*(6), 948–953.

Reinhall, P. G., and P. H. Dahl. (2011). Underwater Mach wave radiation from impact pile driving: Theory and observation. *The Journal of the Acoustical Society of America, 130*(3), 1209–1216.

Rios, L. M., C. Moore, and P. R. Jones. (2007). Persistent organic pollutants carried by synthetic polymers in the ocean environment. *Marine Pollution Bulletin, 54*, 1230–1237.

Roberts, L., S. Cheesman, T. Breithaupt, and M. Elliott. (2015). Sensitivity of the mussel *Mytilus edulis* to substrate-borne vibration in relation to anthropogenically generated noise. *Marine Ecology Progress Series, 538*, 185–195.

Roberts, L., S. Cheesman, M. Elliott, and T. Breithaupt. (2016a). Sensitivity of *Pagurus bernhardus* (L.) to substrate-borne vibration and anthropogenic noise. *Journal of Experimental Marine Biology and Ecology, 474*, 185–194.

Roberts, L., H. R. Harding, I. Voellmy, R. Bruintjes, S. D. Simpson, A. N. Radford, T. Breithaupt, and M. Elliott. (2016b). *Exposure of benthic invertebrates to sediment vibration: From laboratory experiments to outdoor simulated pile-driving.* Paper presented at the Proceedings of Meetings on Acoustics. Dublin, Ireland.

Roberts, S., and M. Hirshfield. (2003). Deep sea corals: Out of sight, but no longer out of mind. *Frontiers in Ecology & the Environment, 2*(3), 123–130.

Rodgers, K. S., P. L. Jokiel, E. K. Brown, S. Hau, and R. Sparks. (2015). Over a Decade of Change in Spatial and Temporal Dynamics of Hawaiian Coral Reef Communities. *Pacific Science, 69*(1), 1–13.

Roe, P., and J. L. Norenburg. (1999). Observations on depth distribution, diversity and abundance of pelagic nemerteans from the Pacific Ocean off California and Hawaii. *Deep-Sea Research, 46*(1), 1201–1220.

Rogers-Bennett, L., P. L. Haaker, T. O. Huff, and P. K. Dayton. (2002). *Estimating Baseline Abundances of Abalone in California for Restoration* (California Cooperative Oceanic Fisheries Investigations [CalCOFI] Reports).

Roleda, M. Y., C. E. Cornwall, Y. Feng, C. M. McGraw, A. M. Smith, and C. L. Hurd. (2015). Effect of Ocean Acidification and pH Fluctuations on the Growth and Development of Coralline Algal Recruits, and an Associated Benthic Algal Assemblage. *PLoS ONE, 10*(10), e0140394.

Rooper, C. N., M. E. Wilkins, C. S. Rose, and C. Coon. (2011). Modeling the impacts of bottom trawling and the subsequent recovery rates of sponges and corals in the Aleutian Islands, Alaska. *Continental Shelf Research, 31*, 1827–1834.

Rooper, C. N., P. J. Etnoyer, K. L. Stierhoff, and J. V. Olson. (2016). Effects of Fishing Gear on Deep-Sea Corals and Sponges in U.S. Waters. In T. F. Hourigan, P. J. Etnoyer, & S. D. Cairns (Eds.), *The State of Deep-Sea Coral and Sponge Ecosystems in the United States* (Vol. NOAA Technical Memorandum NMFS-OHC-3, pp. 4–1–4–19). Silver Spring, MD: National Oceanic and Atmospheric Administration.

Rosen, G., and G. R. Lotufo. (2005). Toxicity and fate of two munitions constituents in spiked sediment exposures with the marine amphipod *Eohaustorius estuarius*. *Environmental Toxicology and Chemistry, 24*(11), 2887–2897.

Rosen, G., and G. R. Lotufo. (2010). Fate and effects of composition B in multispecies marine exposures. *Environmental Toxicology and Chemistry, 9999*(12), 1–8.

Roskov, Y., L. Abucay, T. Orrell, D. Nicolson, T. Kunze, A. Culham, N. Bailly, P. Kirk, T. Bourgoin, R. E. DeWalt, W. Decock, and A. De Weaver. (2015). *Species 2000 & ITIS Catalogue of Life, 2015 Annual Checklist*. Retrieved from http://www.catalogueoflife.org/annual-checklist/2015/.

Ross, S. W., A. W. J. Demopoulos, C. A. Kellogg, C. L. Morrison, M. S. Nizinski, C. L. Ames, T. L. Casazza, D. Gualtieri, K. Kovacs, J. P. McClain, A. M. Quattrini, A. Y. Roa-Varón, and A. D. Thaler. (2012). *Deepwater Program: Studies of Gulf of Mexico Lower Continental Slope Communities Related to Chemosynthetic and Hard Substrate Habitats*. (Open-File Report 2012-1032). Reston, VA: U.S. Geological Survey.

Rossi, T., S. D. Connell, and I. Nagelkerken. (2016). Silent oceans: Ocean acidification impoverishes natural soundscapes by altering sound production of the world's noisiest marine invertebrate. *Proceedings of the Royal Society B: Biological Sciences, 283*(1826), 20153046.

Ryland, J. S., and P. J. Hayward. (1991). *Marine Flora and Fauna of the Northeastern United States. Erect Bryozoa*. (NOAA Technical Report NMFS 99). Washington, DC: National Oceanic and Atmospheric Administration.

Schiff, S. C. (1977). *Effects of Aluminized Fiberglass on Representative Chesapeake Bay Marine Organisms*. Washington, DC: U.S. Department of the Navy, Naval Research Laboratory.

Schlining, K., S. von Thun, L. Kuhnz, B. Sclining, L. Lundsten, N. J. Stout, L. Chaney, and J. Connor. (2013). Debris in the deep: Using a 22-year video annotation database to survey marine litter in Monterey Canyon, central California, USA. *Deep-Sea Research I, 1*(79), 96–105.

Schoeman, D. S., A. McLachlan, and J. E. Dugan. (2000). Lessons from a disturbance experiment in the intertidal zone of an exposed sandy beach. *Estuarine, Coastal and Shelf Science, 50*(6), 869–884.

Setala, O., V. Fleming-Lehtinen, and M. Lehtiniemi. (2014). Ingestion and transfer of microplastics in the planktonic food web. *Environmental Pollution, 185*, 77–83.

Setala, O., J. Norkko, and M. Lehtiniemi. (2016). Feeding type affects microplastic ingestion in a coastal invertebrate community. *Marine Pollution Bulletin, 102*, 95–101.

Shckorbatov, Y., I. Rudneva, V. Pasiuga, V. Grabina, N. Kolchigin, D. Ivanchenko, O. Kazanskiy, V. Shayda, and O. Dumin. (2010). Electromagnetic field effects on *Artemia* hatching and chromatin state. *Central European Journal of Biology, 5*(6), 785–790.

Shorr, J., J. Cervino, C. Lin, R. Weeks, and T. J. Goreau. (2012). Electrical Stimulation Increases Oyster Growth and Survival in Restoration Projects. In T. J. Goreau & R. K. Trench (Eds.), *Innovative Methods of Marine Ecosystem Restoration* (pp. 151–160). Boca Raton, FL: CRC Press.

Sijimol, M. R., and M. Mohan. (2014). Environmental impacts of perchlorate with special reference to fireworks - A review. *Environmental Monitoring and Assessment, 186*, 7203–7210.

Simpson, S. D., A. N. Radford, E. J. Tickle, M. G. Meekan, and A. G. Jeffs. (2011). Adaptive avoidance of reef noise. *PLoS ONE, 6*(2), 1–5.

Small, D. P., P. Calosi, D. Boothroyd, S. Widdicombe, and J. I. Spicer. (2016). The sensitivity of the early benthic juvenile stage of the European lobster *Homarus gammarus* (L.) to elevated pCO_2 and temperature. *Marine Biology, 163*(53).

Smith, G., C. Stamm, and F. Petrovic. (2003). *Haliotis cracherodii*. *IUCN Red List of Threatened Species. Version 2010.1.* Retrieved from www.iucnredlist.org.

Smith, P. N. (2002). Perchlorate in the Environment: Ecological Considerations. Texas Tech University, Lubbock, TX: U.S. Environmental Protection Agency, National Center for Environmental Assessment.

Smith, S. H., and D. E. Marx, Jr. (2016). De-facto marine protection from a Navy bombing range: Farallon de Medinilla, Mariana Archipelago, 1997 to 2012. *Marine Pollution Bulletin, 102*(1), 187–198.

Solan, M., C. Hauton, J. A. Godbold, C. L. Wood, T. G. Leighton, and P. White. (2016). Anthropogenic sources of underwater sound can modify how sediment-dwelling invertebrates mediate ecosystem properties. *Scientific Reports, 6*(20540), 1–9.

Sole, M., M. Lenoir, M. Durfort, M. Lopez-Bejar, A. Lombarte, and M. Andre. (2013). Ultrastructural damage of *Loligo vulgaris* and *Illex coindetii* statocysts after low frequency sound exposure. *PLoS ONE, 8*(10).

Sole, M., M. Lenoir, J. M. Fontuno, M. Durfort, M. van der Schaar, and M. André. (2016). Evidence of Cnidarians sensitivity to sound after exposure to low frequency noise underwater sources. *Scientific Reports, 6*(37979), 1–18.

Sole, M., P. Sigray, M. Lenoir, M. Van der Schaar, E. Lalander, and M. André. (2017). Offshore exposure experiments on cuttlefish indicate received sound pressure and particle motion levels associated with acoustic trauma. *Scientific Reports, 7*(45899), 1–13.

Southern California Marine Institute. (2016). *Southern California Offshore Banks, National Marine Sanctuary Proposal*. Los Angeles, CA: Marine Institute and the Vantuna Research Group and Moore Laboratory of Zoology, Occidental College.

Spalding, M. D., C. Ravilious, and E. P. Green. (2001). *World Atlas of Coral Reefs*. Berkeley, CA: University of California Press.

Spiga, I. (2016). Acoustic response to playback of pile-driving sounds by snapping shrimp. In A. Popper & A. Hawkins (Eds.), *The Effects of Noise on Aquatic Life II, Advances in Experimental Medicine and Biology* (Vol. 875, pp. 1081–1088). New York, NY: Springer.

Srinivasan, A., and T. Viraraghavan. (2009). Perchlorate: Health effects and technologies for its removal from water resources. *International Journal of Environmental Research and Public Health, 6*(4), 1418–1442.

Stanley, J. A., C. A. Radford, and A. G. Jeffs. (2010). Induction of settlement in crab megalopae by ambient underwater reef sound. *Behavioral Ecology, 21*(3), 113–120.

Steimle, F. W., and C. Zetlin. (2000). Reef Habitats in the Middle Atlantic Bight: Abundance, Distribution, Associated Biological Communities, and Fishery Resource Use. *Marine Fisheries Review, 62*(2), 24–42.

Stewart, J. G., and B. Myers. (1980). Assemblages of Algae and Invertebrates in Southern California *Phyllospadix*-Dominated Intertidal Habitats. *Aquatic Botany, 9*, 73–94.

Stierhoff, K. L., M. Neuman, and J. L. Butler. (2012). On the road to extinction? Population declines of the endangered white abalone, *Haliotis sorenseni*. *Biological Conservation, 152*, 46–52.

Stierhoff, K. L., M. Neumann, S. A. Mau, and D. W. Murfin. (2014). *White Abalone at San Clemente Island: Population Estimates and Management Recommendations*. (NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-527). Long Beach, CA: National Marine Fisheries Service.

Talley, T. S., P. K. Dayton, and S. E. Ibarra-Obando. (2000). Tidal flat macrofaunal communities and their associated environments in estuaries of Southern California and Northern Baja California, Mexico. *Estuaries, 23*(1), 97–114.

The Nature Conservancy. (2015). *Reef Resilience: Changes in Storm Patterns*. Retrieved from http://www.reefresilience.org/coral-reefs/stressors/climate-and-ocean-change/changes-in-storm-patterns/.

The Nature Conservancy. (2016). *Reef Resilience: Sea-level Rise*. Retrieved from http://www.reefresilience.org/coral-reefs/stressors/climate-and-ocean-change/sea-level-rise/.

Thiel, M., and I. Kruse. (2001). Status of the Nemertea as predators in marine ecosystems. *Hydrobiologia, 456*, 21–32.

Thompson, B., J. Dixon, S. Schroeter, and D. J. Reish. (1993). Benthic Invertebrates. In M. D. Dailey, D. J. Reish, & J. W. Anderson (Eds.), *Ecology of the Southern California Bight: A Synthesis and Interpretation* (pp. 369–458). Berkeley, CA: University of California Press.

Tierra Data. (2008). *Naval Auxiliary Landing Field, San Clemente Island Black Abalone (Haliotis cracherodii) Survey.* San Diego, CA: Naval Facilities Engineering Command Southwest.

Tittensor, D. P., A. R. Baco, P. E. Brewin, M. R. Clark, M. Consalvey, J. Hall-Spencer, A. A. Rowden, T. Schlacher, K. I. Stocks, and A. D. Rogers. (2009). Predicting global habitat suitability for stony corals on seamounts. *Journal of Biogeography, 36*, 1111–1128.

Torres, M. E., J. McManus, and C. Huh. (2002). Fluid seepage along the San Clemente fault scarp: Basin-wide impact on barium cycling. *Earth and Planetary Science Letters, 203*, 181–194.

Towle, E. K., A. C. Baker, and C. Langdon. (2016). Preconditioning to high CO_2 exacerbates the response of the Caribbean branching coral *Porites porites* to high temperature stress. *Marine Ecology Progress Series, 546*, 75–84.

Treible, L. M., K. A. Pitt, S. G. Klein, and R. H. Condon. (2018). Exposure to elevated pCO_2 does not exacerbate reproductive suppression of *Aurelia aurita* jellyfish polyps in low oxygen environments. *Marine Ecology Progress Series, 591*, 129–139.

Tsao, F., and L. E. Morgan. (2005). Corals That Live On Mountaintops. *The Journal of Marine Education, 21*(4), 9–11.

U.S. Army Corps of Engineers. (2001). *Environmental Effects of Beach Nourishment Projects*.

U.S. Army Corps of Engineers. (2012). *New York and New Jersey Harbor Deepening Project: 2012 Benthic Recovery Report*. (Contract #: W912DS-11-D-0008 – Task Order # 5). New York, NY: New York District.

U.S. Department of the Navy. (1999). *Environmental Effects of RF Chaff: A Select Panel Report to the Undersecretary of Defense for Environmental Security*. Washington, DC: U.S. Department of the Navy, Naval Research Laboratory.

U.S. Department of the Navy. (2010). *Jacksonville Range Complex Operating Area Undersea Warfare Training Range Bottom Mapping and Habitat Characterization, Florida. Final Cruise Report*. Jacksonville, FL: Naval Facilities Engineering Command Atlantic.

U.S. Department of the Navy. (2011). *CC Range Bottom Mapping and Habitat Characterization, Florida. Final Cruise Report*. Norfolk, VA: Naval Facilities Engineering Command Atlantic.

U.S. Department of the Navy. (2013a). *Military Expended Material Shrimp Fisheries Study in the U.S. South Atlantic and Eastern Gulf of Mexico*. Newport, RI: Naval Undersea Warfare Center Division.

U.S. Department of the Navy. (2013b). *Ecosystem Technical Report for the Hawaii-Southern California Training and Testing (HSTT) Environmental Impact Statement*. Pearl Harbor, HI: Naval Facilities Engineering Command, Pacific.

U.S. Department of the Navy, and National Oceanic and Atmospheric Administration. (2016). *Memorandum of Agreement Between the Department of the Navy and the National Oceanic and Atmospheric Administration, National Marine Fisheries Service Regarding the Establishment of a Seven-Year Plan to Support the Recovery of the Endangered White Abalone at Tanner and Cortes Banks*: Department of the Navy and National Marine Fisheries Service.

U.S. Environmental Protection Agency. (2014). *Technical Fact Sheet: Perchlorate*. (Environmental Protection Agency 505-F-14-003). Washington, DC: Office of Solid Waste and Emergency Response.

U.S. Fish and Wildlife Service. (2011). *Recovery Plan for Hawaiian Waterbirds, Second Revision*. Portland, OR: U.S. Fish and Wildlife Service, Region 1.

U.S. Geological Survey. (2016). *Sea-Level Rise and Climate Change Impacts to Reefs*. *Pacific Coastal and Marine Science Center.* Retrieved from http://coralreefs.wr.usgs.gov/climatechg.html.

University of California Berkeley. (2010a). *Introduction to the Foraminifera*. Retrieved from http://www.ucmp.berkeley.edu/foram/foramintro.html.

University of California Berkeley. (2010b). *Introduction to the Platyhelminthes*. Retrieved from http://www.ucmp.berkeley.edu/platyhelminthes/platyhelminthes.html.

University of California Berkeley. (2010c). *Introduction to Porifera*. Retrieved from http://www.ucmp.berkeley.edu/porifera/porifera.html.

University of California Berkeley. (2010d). *Introduction to the Bryozoa: "Moss animals"*. Retrieved from http://www.ucmp.berkeley.edu/bryozoa/bryozoa.html.

University of California Berkeley. (2010e). *Radiolaria: Life history and ecology*. Retrieved from http://www.ucmp.berkeley.edu/protista/radiolaria/rads.html.

University of California Davis. (2017). *Spawning success for white abalone*. Retrieved from http://blogs.ucdavis.edu/egghead/2015/01/29/spawning-success-for-white-abalone/.

Van Soest, R. W., N. Boury-Esnault, J. Vacelet, M. Dohrmann, D. Erpenbeck, N. J. De Voogd, N. Santodomingo, B. Vanhoorne, M. Kelly, and J. N. Hooper. (2012). Global diversity of sponges (Porifera). *PLoS ONE, 7*(4), e35105.

Vazzana, M., M. Celi, G. Maricchiolo, L. Genovese, V. Corrias, E. M. Quinci, G. de Vincenzi, V. Maccarrone, G. Cammilleri, S. Mazzola, G. Buscaino, and F. Filiciotto. (2016). Are mussels able to distinguish underwater sounds? Assessment of the reactions of *Mytilus galloprovincialis* after exposure to lab-generated acoustic signals. *Comparative Biochemistry and Physiology, Part A, 201*, 61–70.

Verkaik, K., J. Hamel, and A. Mercier. (2016). Carry-over effects of ocean acidification in a cold-water lecithotrophic holothuroid. *Marine Ecology Progress Series, 557*, 189–206.

Vermeij, M. J. A., K. L. Marhaver, C. M. Huijbers, I. Nagelkerken, and S. D. Simpson. (2010). Coral larvae move toward reef sounds. *PLoS ONE, 5*(5), e10660.

Veron, J. (2013). Overview of the taxonomy of zooxanthellate Sceractinia. *Zoological Journal of the Linnean Society, 169*, 485–508.

Voiland, A. (2013). *In a Warming World, Storms May Be Fewer but Stronger*. Retrieved from http://earthobservatory.nasa.gov/Features/ClimateStorms/page1.php.

Von Moos, N., P. Burkhardt-Holm, and A. Kohler. (2012). Uptake and Effects of Microplastics on Cells and Tissue of the Blue Mussel *Mytilus edulis L.* after an Experimental Exposure. *Environmental Science and Technology, 46*, 11327–11335.

Waikiki Aquarium. (2009a). *Marine life profile: Ghost crab*. Retrieved from http://www.waquarium.org/marinelifeprofiles_ed.html.

Waikiki Aquarium. (2009b). *Marine life profile: Hawaiian spiny lobster*. Retrieved from http://www.waquarium.org/marinelifeprofiles_ed.html.

Waikiki Aquarium. (2009c). *Marine life profile: Hawaiian slipper lobsters*. Retrieved from http://www.waquarium.org/marinelifeprofiles_ed.html.

Wale, M. A., S. D. Simpson, and A. N. Radford. (2013a). Size-dependent physiological responses of shore crabs to single and repeated playback of ship noise. *Biology Letters, 9*(20121194).

Wale, M. A., S. D. Simpson, and A. N. Radford. (2013b). Noise negatively affects foraging and antipredator behaviour in shore crabs. *Animal Behaviour, 86*, 111–118.

Walter, T. C., and G. Boxshall. (2017). *World of Copepods database*. Retrieved from http://www.marinespecies.org/copepoda/.

Wang, W. X., and P. S. Rainbow. (2008). Comparative approaches to understand metal bioaccumulation in aquatic animals. *Comparative Biochemistry and Physiology, Part C, 148*(4), 315–323.

Watters, D. L., M. M. Yoklavich, M. S. Love, and D. M. Schroeder. (2010). Assessing marine debris in deep seafloor habitats off California. *Marine Pollution Bulletin, 60*, 131–138.

Watts, A. J. R., C. Lewis, R. M. Goodhead, S. J. Beckett, J. Moger, C. R. Tyler, and T. Galloway. (2014). Uptake and retention of microplastics by the shore crab *Carcinus maenas*. *Environmental Science and Technology, 48*, 8823–8830.

Wei, C. L., G. T. Rowe, C. C. Nunnally, and M. K. Wicksten. (2012). Anthropogenic "Litter" and macrophyte detritus in the deep Northern Gulf of Mexico. *Marine Pollution Bulletin, 64*(5), 966–973.

Western Pacific Regional Fishery Management Council. (2001). *Final Fishery Management Plan for Coral Reef Ecosystems of the Western Pacific Region*. Honolulu, HI: Western Pacific Regional Fishery Management Council.

Western Pacific Regional Fishery Management Council. (2009). *Fishery Ecosystem Plan for the Hawaii Archipelago*. Honolulu, HI: Western Pacific Regional Fishery Management Council.

Wheat, C. G., H. W. Jannasch, J. N. Plant, C. L. Moyer, F. J. Sansone, and G. M. McMurtry. (2000). Continuous sampling of hydrothermal fluids from Loihi Seamount after the 1996 event. *Journal of Geophysical Research, 105*(B8), 19353–19367.

White, H. K., P. Y. Hsing, W. Cho, T. M. Shank, E. E. Cordes, A. M. Quattrini, R. K. Nelson, R. Camilli, A. W. Demopoulos, C. R. German, J. M. Brooks, H. H. Roberts, W. Shedd, C. M. Reddy, and C. R. Fisher. (2012). Impact of the Deepwater Horizon oil spill on a deep-water coral community in the Gulf of Mexico. *Proceedings of the National Academy of Sciences of the United States of America, 109*(50), 20303–20308.

Whitmire, C. E., and M. E. Clarke. (2007). *State of Deep Coral Ecosystems of the U.S. Pacific Coast: California to Washington* (The State of Deep Coral Ecosystems of the United States). Silver Spring, MD: U.S. Department of Commerce and National Oceanic and Atmospheric Administration.

Wilber, D., D. Clarke, G. Ray, and R. Dolah. (2009). *Lessons Learned from Biological Monitoring of Beach Nourishment Projects*. Tempe, AZ: Western Dredging Association.

Wilkens, S. L., J. A. Stanley, and A. G. Jeffs. (2012). Induction of settlement in mussel (*Perna canaliculus*) larvae by vessel noise. *Biofouling, 28*(1), 65–72.

Wilkinson, C. (2002). Executive Summary. In C. Wilkinson (Ed.), *Status of Coral Reefs of the World: 2002* (pp. 7–31). Townsville, Australia: Global Coral Reef Monitoring Network.

Wilson, C. L., D. P. Arfsten, R. L. Carpenter, W. K. Alexander, and K. R. Still. (2002). Effect of Navy chaff release on aluminum levels in an area of the Chesapeake Bay. *Ecotoxicology Environmental Safety, 52*(2), 137–142.

Wilson, M., R. T. Hanlon, P. L. Tyack, and P. T. Madsen. (2007). Intense ultrasonic clicks from echolocating toothed whales do not elicit anti-predator responses or debilitate the squid, *Loligo pealeii*. *Biology Letters, 3*, 225–227.

Wood, A. C. L., P. K. Probert, A. A. Rowden, and A. M. Smith. (2012). Complex habitat generated by marine bryozoans: a review of its distribution, structure, diversity, threats and conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems, 22*(4), 547–563.

Wood, J. B., and C. Day. (2005). *CephBase*. Retrieved from http://www.cephbase.utmb.edu/.

Woodruff, D. L., V. I. Cullinan, A. E. Copping, and K. E. Marshall. (2013). *Effects of Electromagnetic Fields on Fish and Invertebrates* (Task 2.1.3: Effects of Aquatic Organisms, Fiscal Year 2012 Progress Report). Washington, DC: U.S. Department of Energy.

Woods Hole Oceanographic Institution. (2015). *Life at Vents & Seeps*. Retrieved from https://www.whoi.edu/main/topic/life-at-vents-seeps.

World Register of Marine Species Editorial Board. (2015). *Towards a World Register of Marine Species*. Retrieved from http://www.marinespecies.org/about.php

Wright, S. L., D. Rowe, R. C. Thompson, and T. S. Galloway. (2013). Microplastic ingestion decreases energy reserves in marine worms. *Current Biology, 23*(23), R1031–R1033.

Yender, R. A., J. Michel, and R. Hoff. (2010). *Oil Spills in Coral Reefs: Planning & Response Considerations*. Silver Spring, MD: National Oceanic and Atmospheric Administration.

Yoklavich, M., T. Laidig, A. Taylor, D. Watters, L. Krigsman, and M. Love. (2013). *A Characterization of the Christmas Tree Black Coral (Antipathes dendrochristos) Community on Three Seamounts in the*

Southern California Bight from a Survey using a Manned Submersible. Santa Barbara, CA: National Oceanic and Atmospheric Administration Deep-Sea Coral Research and Technology Program.

Yoklavich, M. M., T. E. Laidig, K. Graiff, M. E. Clarke, and C. E. Whitmire. (2017). Incidence of disturbance and damage to deep-sea corals and sponges in areas of high trawl bycatch near the California and Oregon border. *Deep-Sea Research Part II*.

Young, G. A. (1991). *Concise Methods for Predicting the Effects of Underwater Explosions on Marine Life*. Silver Spring, MD: Naval Surface Warfare Center.

Zabawa, C., and C. Ostrom. (1980). *Final Report on the Role of Boat Wakes in Shore Erosion in Anne Arundel County, Maryland*. Annapolis, MD: Maryland Department of Natural Resources.

Zabin, C. J., E. M. Danner, E. P. Baumgartner, D. Spafford, K. A. Miller, and J. S. Pearse. (2013). A comparison of intertidal species richness and composiiton between Central California and Oahu, Hawaii. *Marine Ecology, 34*, 131–156.

Zhao, S., C. Feng, W. Quan, X. Chen, J. Niu, and Z. Shen. (2012). Role of living environments in the accumulation characteristics of heavy metals in fishes and crabs in the Yangtze River Estuary, China. *Marine Pollution Bulletin, 64*(6), 1163–1171.

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3.5 Habitats

PREFERRED ALTERNATIVE SYNOPSIS

The United States Department of the Navy considered all potential stressors that abiotic substrate as a habitat for marine life could be exposed to from the Proposed Action. The following conclusions have been reached for the Preferred Alternative (Alternative 1):

- Acoustics: Acoustic stressors are not applicable to habitats due to the fact that habitats do not have hearing capabilities and are not analyzed further in this section.
- Explosives: Most of the high-explosive military expended materials would detonate at or near the water surface. The surface area of bottom substrate affected would be a tiny fraction of the total training and testing area available in the Study Area.
- Energy: Energy stressors are not applicable to habitats because of the lack of sensitivity of habitats and are not analyzed further in this section.
- Physical Disturbance and Strike: Most seafloor devices would be placed in areas that would result in minor and temporary bottom substrate impacts. Once on the seafloor and over time, military expended materials would be buried by sediment, corroded from exposure to the marine environment, or colonized by benthic organisms. The surface area of bottom substrate affected over the short-term would be a tiny fraction of the total training and testing area available in the Study Area.
- Entanglement: Entanglement stressors are not applicable because habitats do not have the ability to become "entangled" by materials. The potential for expended material to cover a substrate is discussed in Section 3.5.3.4 (Physical Disturbance and Strike Stressors).
- Ingestion: Ingestion stressors are not applicable because habitats lack the ability to ingest; therefore, ingestion stressors are not analyzed for habitats.
- Secondary stressors: Secondary stressors are not applicable to habitats as they are not susceptible to impacts from secondary stressors and are not analyzed further in this section.

3.5.1 Introduction

This chapter provides the analysis of potential impacts on marine and estuarine nonliving (abiotic) substrates found in the Hawaii-Southern California Training and Testing (HSTT) Study Area (Study Area). This section provides an introduction to the abiotic habitats that occur in the Study Area. The following sections describe the abiotic habitats in greater detail (Section 3.5.2, Affected Environment) and evaluate the potential impacts of testing and training activities on abiotic substrates (Section 3.5.3, Environmental Consequences). A summary of the potential impacts on abiotic habitats for each alternative is provided in Section 3.5.4 (Summary of Potential Impacts on Habitats).

The Study Area covers a range of marine and estuarine habitats, each supporting communities of organisms that may vary by season and location. The intent of this section is to cover abiotic habitat features and impacts that are not addressed in the individual living resources chapters. The water column and bottom substrate provide the necessary habitats for living resources, including those that form biotic habitats such as aquatic plant beds and coral reefs, which are discussed in other sections (e.g., Section 3.3, Vegetation; Section 3.4, Invertebrates). The potential for training or testing to impact the chemical quality of abiotic habitat is addressed in a separate section (Section 3.2, Sediments and Water Quality). Potential impacts to organisms and biotic habitats are covered in their respective resource sections. Potential impacts to the water column are not addressed in this section because the effects would not be associated with a change in habitat type, but rather would be limited to changes in water quality, which are addressed in Section 3.2 (Sediments and Water Quality). Further, the water column is discussed as a type of essential fish habitat (EFH) in the Navy's Essential Fish Habitat Assessment. A summary of the assessment can be found in Section 6.1.3 (Magnuson-Stevens Fishery Conservation and Management Act). Acoustic energy transmitting through the water column may temporarily affect the suitability of the water column as habitat for certain species of invertebrates, fish, marine mammals, and sea turtles. The potential effects on species that use the water column as habitat are addressed in the sections on those specific resources (e.g., Section 3.4, Invertebrates; Section 3.6, Fishes; Section 3.7, Marine Mammals; Section 3.8, Reptiles). Therefore, this section only addresses impacts to habitat substrates.

Table 3.5-1 presents the types of habitats discussed in this section in relation to the open ocean areas and bays and harbors in which they occur. Habitat types are derived from *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al., 1979), which includes a basic classification of intertidal shores, subtidal bottoms, and associated substrates. Whereas there are many classification systems spanning a range of spatial dimensions and granularity (Allee et al., 2000; Cowardin et al., 1979; Howell et al., 2010; Kendall et al., 2001; United Nations Educational Scientific and Cultural Organization, 2009; Valentine et al., 2005), there are basically three types of abiotic substrates based on the grain size of unconsolidated material: "soft bottom" (e.g., sand, mud), "Intermediate" (e.g., cobble, gravel), and "hard bottom" (e.g., bedrock, boulders).

Table 3.5-1: Habitat Types Within the Open Ocean of the Hawaii-Southern California Training and Testing Study Area

		Presence in Study Area	
Substrate Type	***Subtypes (Examples)***	***Open Ocean***	***Bays and Harbors***
Intertidal Shores			
Soft Shores	Beach, Tidal Delta/Flat	-	Pearl Harbor, San Diego Bay
Intermediate Shores	Cobble/Gravel, Mixed	-	-
Hard Shores	Rocky Intertidal	-	Pearl Harbor
Subtidal Bottoms			
Soft Bottoms	Channel, Flat, Shoal	Presumed to be widespread throughout the Pacific	Pearl Harbor, San Diego Bay
Intermediate Bottoms	Cobble/Gravel, Mixed	Relatively common, typically occurring at transitional areas between hard and soft bottoms	San Diego Bay
Hard Bottoms	Rocky Subtidal	Most common near the Hawaiian Islands and in deeper waters off the southern California coast.	Pearl Harbor, San Diego Bay
Intertidal Shore or Subtidal Bottom			
Artificial Structures	Artificial reefs, ship wrecks, oil/gas platforms, bulkheads, piers	Found throughout the Study Area in nearshore and offshore locations	Pearl Harbor, San Diego Bay

Spatial and temporal variation in abiotic substrate is created by the interplay of underlying geology, currents, and water quality at a location. The modified classification system provided in Table 3.5-1 starts at the subsystem level (e.g., intertidal shores and subtidal bottoms) and focuses analysis on a modified class level (e.g., soft shores/bottoms, intermediate shores/bottoms, hard shores/bottoms). The listed subsystems and classes refer to non-living substrates and are differentiated from living structures on the substrate. Living structures on the substrate are termed biotic habitats, and include wetland shores, aquatic plant beds (i.e., attached macroalgae, rooted vascular plants), sedentary invertebrate beds, and reefs (e.g., corals, oysters).

The physical characteristics of substrates, whether they are unconsolidated and soft, or hard and rocky, are key factors in structuring sedentary biological communities (Nybakken, 1993). Physical characteristics of the different substrate types represent a viable target for the best available mapping technology (i.e., multibeam sonar) and are useful for characterizing Navy impacts (e.g., explosive charges on soft bottom).

Differences among the physical and chemical environments of various abiotic habitats dictate both the variety and abundance of sessile marine organisms supported. The assessment in this section focuses on the potential for testing or training activities to change or modify the physical properties of abiotic substrates and their ecological functions as habitat for organisms. A physical impact on abiotic marine habitats is anticipated where training or testing activities have the potential to displace sediment, convert one substrate type into another (e.g., bedrock to unconsolidated soft bottom), alter vertical relief, or modify structural complexity.

3.5.2 AFFECTED ENVIRONMENT

3.5.2.1 General Background

Abiotic marine habitats vary according to geographic location, underlying geology, hydrodynamics, atmospheric conditions, and suspended particles and associated biogenic features. Sediments may be derived from material eroded from land sources associated with coastal bluff erosion and sediment flows from creeks and rivers, which may create channels, tidal deltas, intertidal and subtidal flats, and shoals of unconsolidated material along the shorelines and estuaries. Sediments derived from volcanic rock are common in the Hawaiian Islands and occur in localized areas of Southern California (i.e., San Clemente Island) within the Study Area. In the Hawaiian Islands, nearshore sediments also are derived from biogenic sources (i.e., corals).

The influence of land-based nutrients on habitat type and sediment increases with proximity to streams, bays and harbors, and nearshore waters. In the open ocean, gyres, eddies, and oceanic currents influence the distribution of organisms. Major bottom features in the offshore areas of the range complexes include shelves, banks, breaks, slopes, canyons, plains, and seamounts. Geologic features such as these affect the hydrodynamics of the ocean water column (i.e., currents, gyres, upwellings) as well as living resources present. Bathymetric features of the Study Area are described in Section 3.0.2.2 (Bathymetry). The distribution of abiotic marine habitats in the range complexes is described in their respective sections below.

The majority of the Study Area lies outside of state waters. State waters extend from shore to 3 nautical miles (NM) in Hawaii and California. Therefore, relatively little of the Study Area includes intertidal and shallow subtidal areas in state waters, where numerous ecosystem types are exclusively present (i.e., salt/brackish marsh, mangrove, seagrass beds, kelp forests, rocky reefs). Intertidal abiotic habitats (i.e., beaches, tidal deltas, mudflats, rocky shores) represent only a small portion of the Study Area; however, they are addressed along with all other habitats (where those habitats overlap with naval training and testing activities).

3.5.2.1.1 Shore Habitats

3.5.2.1.1.1 Description

Soft Shores

Soft shores include all aquatic habitats that have three characteristics: (1) unconsolidated substrates with less than 25 percent areal cover of stones, boulders, or bedrock, (2) unconsolidated sediment composed of predominantly sand or mud, and (3) primarily intertidal water regimes (Cowardin et al., 1979). Note that a shoreline covered in vegetation (e.g., marsh) could still have a soft substrate foundation. Soft shores include beaches, tidal flats/deltas, and streambeds of the tidal riverine and estuarine systems.

Intermittent or intertidal channels of the riverine system and intertidal channels of the estuarine system are classified as streambed. Intertidal flats, also known as tidal flats or mudflats, consist of loose mud, silt, and fine sand with organic-mineral mixtures that are regularly exposed and flooded by the tides (Karleskint et al., 2006). Muddy and fine sediment tends to be deposited where wave energy is low, such as in sheltered bays and estuaries (Holland & Elmore, 2008). Mudflats are typically unvegetated, but may be covered with encrusting microscopic algae (e.g., diatoms) or sparsely vegetated with low-growing aquatic plants (e.g., macroalgae/seaweed, seagrass). Muddy intertidal habitat occurs most often as part of a patchwork of intertidal habitats that may include rocky shores, tidal creeks, sandy beaches, salt marshes, and mangroves. A flat area of unconsolidated sediment that is covered in aquatic plants could be considered an aquatic bed growing on soft shore habitat. While river deltas are created by soil deposits forming from the outflow of the water, such as at the mouth of the Mississippi River, tidal deltas are depositions of sediment left by the diurnal tides and their resulting currents. Therefore, tidal (or tide-dominated) deltas typically occur in locations of large tidal ranges or high tidal current speeds (SEPM Strata, 2018).

Beaches form through the interaction of waves and tides, as particles are sorted by size and are deposited along the shoreline (Karleskint et al., 2006). Wide flat beaches with fine-grained sands occur where wave energy is limited. Narrow steep beaches of coarser sand form where energy and tidal ranges are high (Speybroeck et al., 2008). Three zones characterize beach habitats: (1) dry areas above the mean high water, (2) wrack lines (the area where seaweed and debris is deposited at high tide) and (3) a high-energy intertidal zone (area between high and low tide).

Intermediate Shores

Intermediate shores include all aquatic habitats with the following three characteristics: (1) substrates with at least 25 percent cover in particles smaller than stones, (2) unconsolidated substrate is predominantly gravel or cobble-sized, and (3) primarily intertidal water regimes. These areas may or may not be stable enough for attached vegetation or invertebrates, depending on overlying hydrology and water quality. Note that a shoreline with vegetation (e.g., macroalgae, seagrass) could still have an intermediate substrate foundation. Hard corals may grow in these habitats in the Hawaiian Islands.

Hard Shores

Rocky shores include intertidal aquatic habitats characterized by bedrock, stones, and/or boulders that cover 75 percent or more of an area (Cowardin et al., 1979). Note that a shoreline covered in vegetation could still have a hard substrate foundation. Rocky intertidal shores are areas of bedrock occupying the area between high and low tide lines (Menge & Branch, 2001). Extensive rocky shorelines can be interspersed with sandy areas, estuaries, or river mouths.

Environmental gradients between hard shorelines and subtidal habitats are determined by wave action, depth, frequency of tidal inundation, and stability of substrate (Cowardin et al., 1979). Where wave energy is extreme, only rock outcrops may persist. In lower energy areas, a mixture of rock sizes will occur in the intertidal zone. Intertidal rocky shores provide substrate for attached macroalgae and sessile invertebrates.

3.5.2.1.1.2 Distribution

Soft Shores

Tidal flats occur on a variety of scales in virtually all estuaries and bays in the Hawaii Range Complex and Southern California Range Complex. In the Hawaiian portion of the Study Area, beaches are common along the lagoon reaches of atoll islets, along the coasts, and in embayments of the main and Northwestern Hawaiian Islands. Significant sandy beach habitat occurs primarily on the western and southern sides of the islands (Maragos, 2000). About 82 percent of Southern California's coastline is sandy beach habitat (Allen & Pondella, 2006). The Southern California portion of the Study Area has extensive beaches, although few stretches are undisturbed by human activity (U.S. Department of Commerce et al., 2008).

Intermediate Shores

In the Hawaii Range Complex, intermediate intertidal habitat, including unconsolidated limestone and volcanic rock, occurs throughout the Hawaiian Islands in localized areas, typically near hard shorelines where physical conditions prevent sand from accumulating (Maragos, 2000). Intermediate intertidal habitats occur on the Channel Islands and along the mainland within the Study Area. The majority of intermediate shores occur in transitional areas between hard shores and soft shores. Intermediate shorelines also may occur at beaches where hard substrate underlies sand and rocks become exposed during periods of shoreline erosion (e.g., several beaches in San Diego County).

Hard Shores

In the Hawaii Range Complex, rocky intertidal habitat including limestone and volcanic rock occurs throughout the Hawaiian Islands in localized areas wherever physical conditions prevent sand from accumulating (Maragos, 2000). In the Southern California portion of the Study Area, rocky intertidal habitat is most extensive on the offshore Channel Islands. Hard shores are localized in distribution along the mainland of Southern California. In numerous locations within the HSTT Study Area, artificial hard substrates (e.g., rock riprap, seawalls) have been placed to reduce storm damage and erosion along shorelines and in estuaries.

3.5.2.1.2 Bottom Habitats

3.5.2.1.2.1 Description

Soft Bottom

Soft bottoms include all aquatic habitats with the following three characteristics: (1) at least 25 percent cover of particles smaller than stones, (2) unconsolidated sediment is predominantly mud or sand, and (3) primarily subtidal water regimes (Cowardin et al., 1979). Soft bottom forms the substrate of channels, shoals, subtidal flats, and other features of the bottom. Sandy channels emerge where strong currents connect estuarine and ocean water columns. Shoals or capes form where sand is deposited by interacting, sediment-laden currents. Subtidal flats occur between soft shores and channels or shoals. The continental shelf extends seaward of the shoals and inlet channels and includes relatively coarse-grained, soft bottom habitats. Relatively finer-grained sediments collect off the shelf break, continental slope, and abyssal plain. Organisms characteristic of soft bottom environments, such as worms and clams, may be found at all depths where there is sufficient oxygen and sediment accumulation (Nybakken, 1993).

Intermediate Bottom

Intermediate bottom includes all aquatic habitats with the following three characteristics: (1) substrates with at least 25 percent cover in particles smaller than stones, (2) unconsolidated substrate is predominantly gravel or cobble-sized, and (3) primarily subtidal water regimes. These areas may or may not be stable enough for attached vegetation or sedentary invertebrates, depending on overlying hydrology and water quality.

Hard Bottom

Hard bottom includes all aquatic habitats with substrates having a surface of stones, boulders, or bedrock (75 percent or greater coverage) (Cowardin et al., 1979). Subtidal rocky habitat occurs as extensions of intertidal rocky shores and as isolated offshore outcrops. The shapes and textures of the larger rock assemblages and the fine details of cracks and crevices are determined by the type of rock, the wave energy, and other local variables (Davis, 2009). Maintenance of mostly low relief hard bottom (e.g., bedrock) requires wave energy and/or currents sufficient to sweep sediment away (Lalli & Parsons, 1993) or offshore areas lacking a significant sediment supply; therefore, rocky reefs are rare on broad coastal plains near sediment-laden rivers and are more common on high-energy shores and beneath strong bottom currents, where sediments cannot accumulate.

In deep waters of the Pacific Ocean, there are also a number of chemosynthetic communities (cold seeps and thermal vents), which tend to support unique biotic communities. A cold seep, or cold vent, is an area of the ocean floor where chemical fluid seepage occurs. Cold seeps develop unique topography over time, where reactions between methane and seawater create carbonate rock formations and reefs. A thermal, or hydrothermal, vent is a fissure in the seafloor where geothermally heated water is released. Hydrothermal vents are known near the main Island of Hawaii. Cold seeps occur in association with multiple fault systems off Southern California. Hard substrate in the abyssal zone and some locations landward of the deep ocean are typically devoid of encrusting or attached organisms due to the scarcity of drifting food particles in the deep ocean (Nybakken, 1993).

3.5.2.1.2.2 Distribution

Soft, intermediate, and hard bottom habitats occur in both range complexes and the open ocean. However, the distribution of different bottom types varies across the Study Area (Figure 3.5-1 through Figure 3.5-8) and is depicted by at least 10 datasets. These datasets were ranked by quality and assembled into the non-overlapping mosaic as described in *Building and Maintaining a Comprehensive Database and Prioritization Scheme for Overlapping Habitat Data* (U.S. Department of the Navy, 2018). The datasets employ a variety of data collection techniques and analysis techniques to characterize the seafloor; results are summarized below. Thousands of acres of lower quality data were superseded by high quality data in the process of creating the non-overlapping abiotic substrate maps for the HSTT study area.

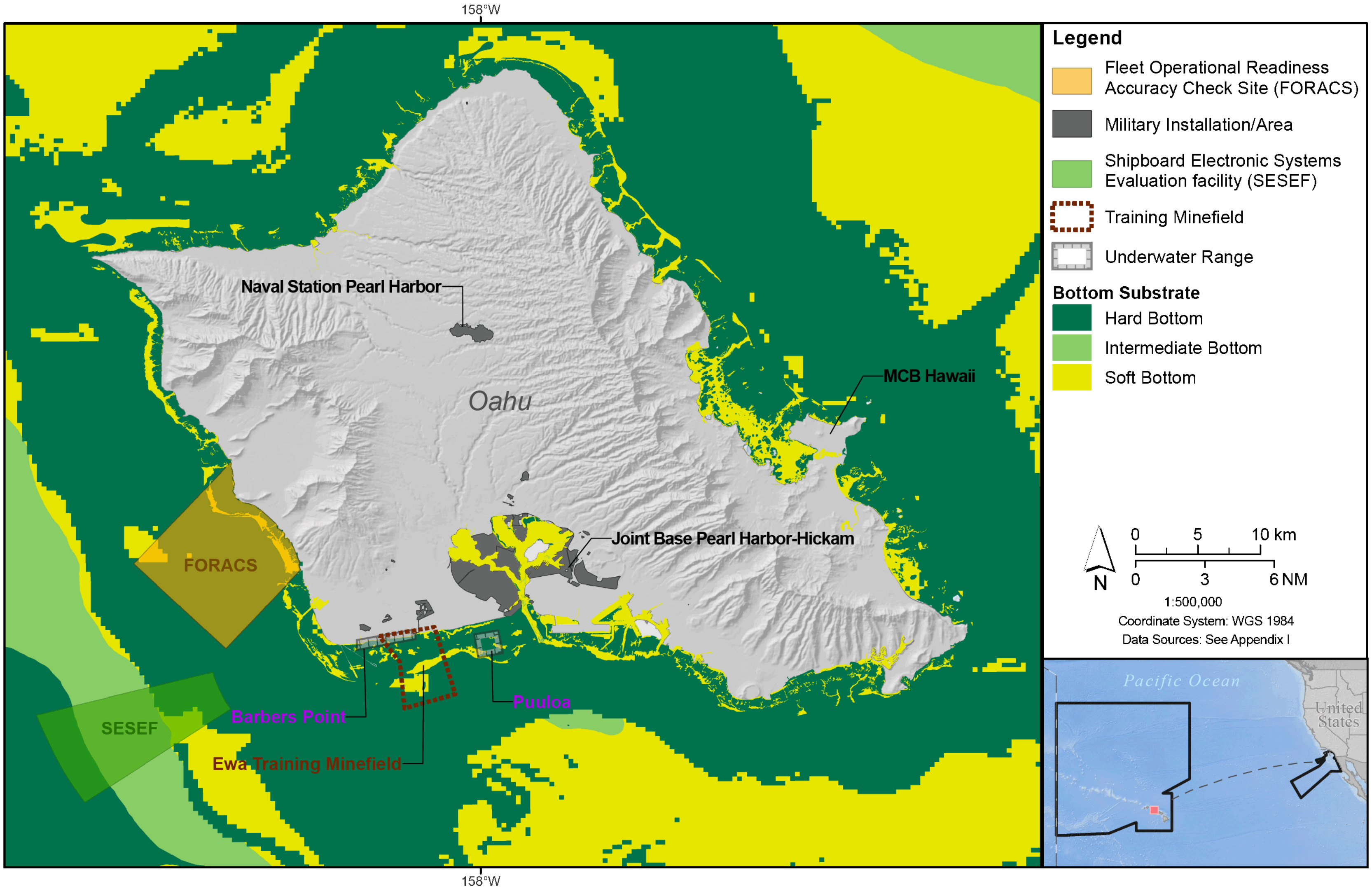


Figure 3.5-1: Bottom Substrate Composition – Island of Oahu

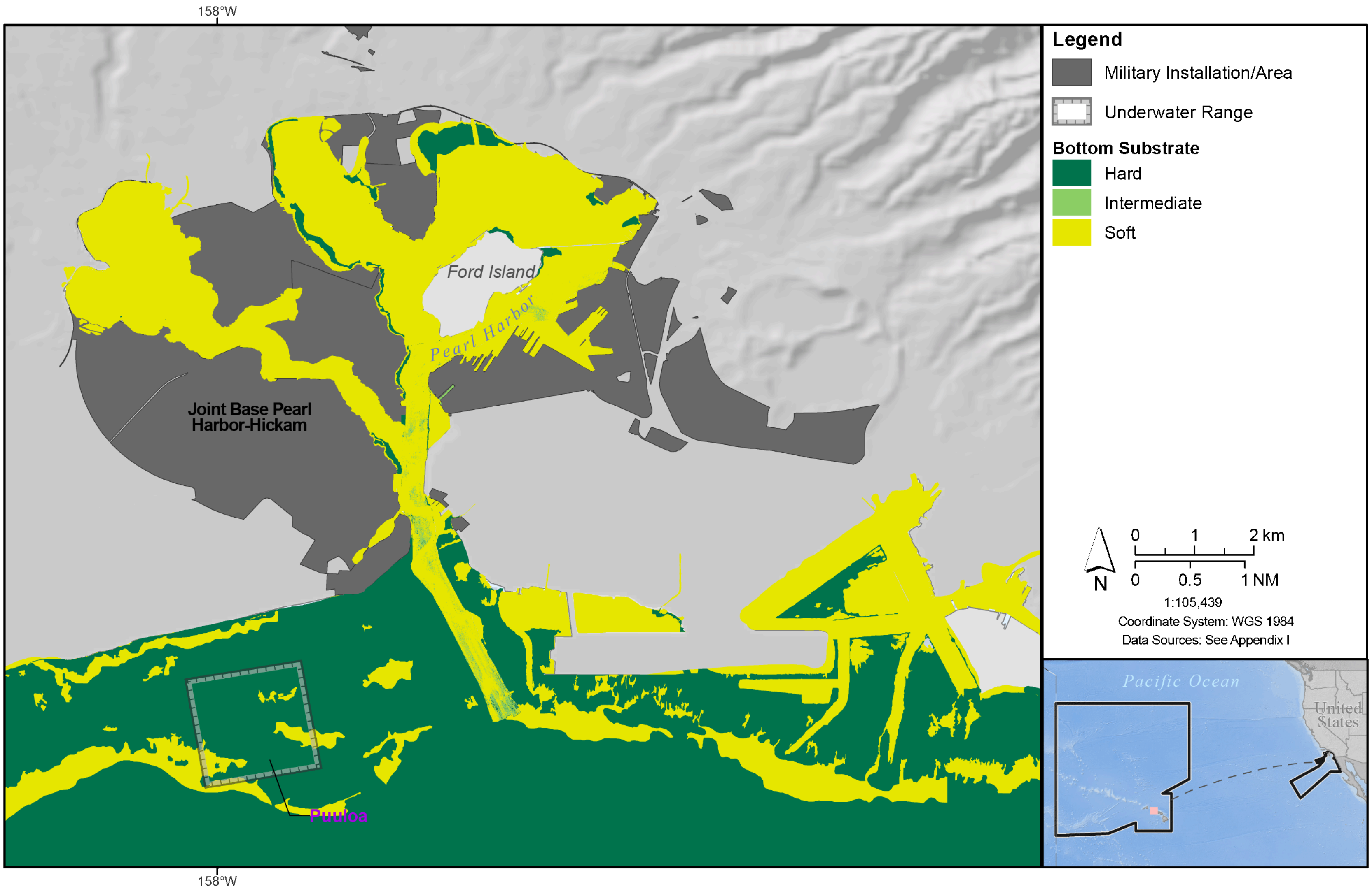


Figure 3.5-2: Bottom Substrate Composition – Pearl Harbor

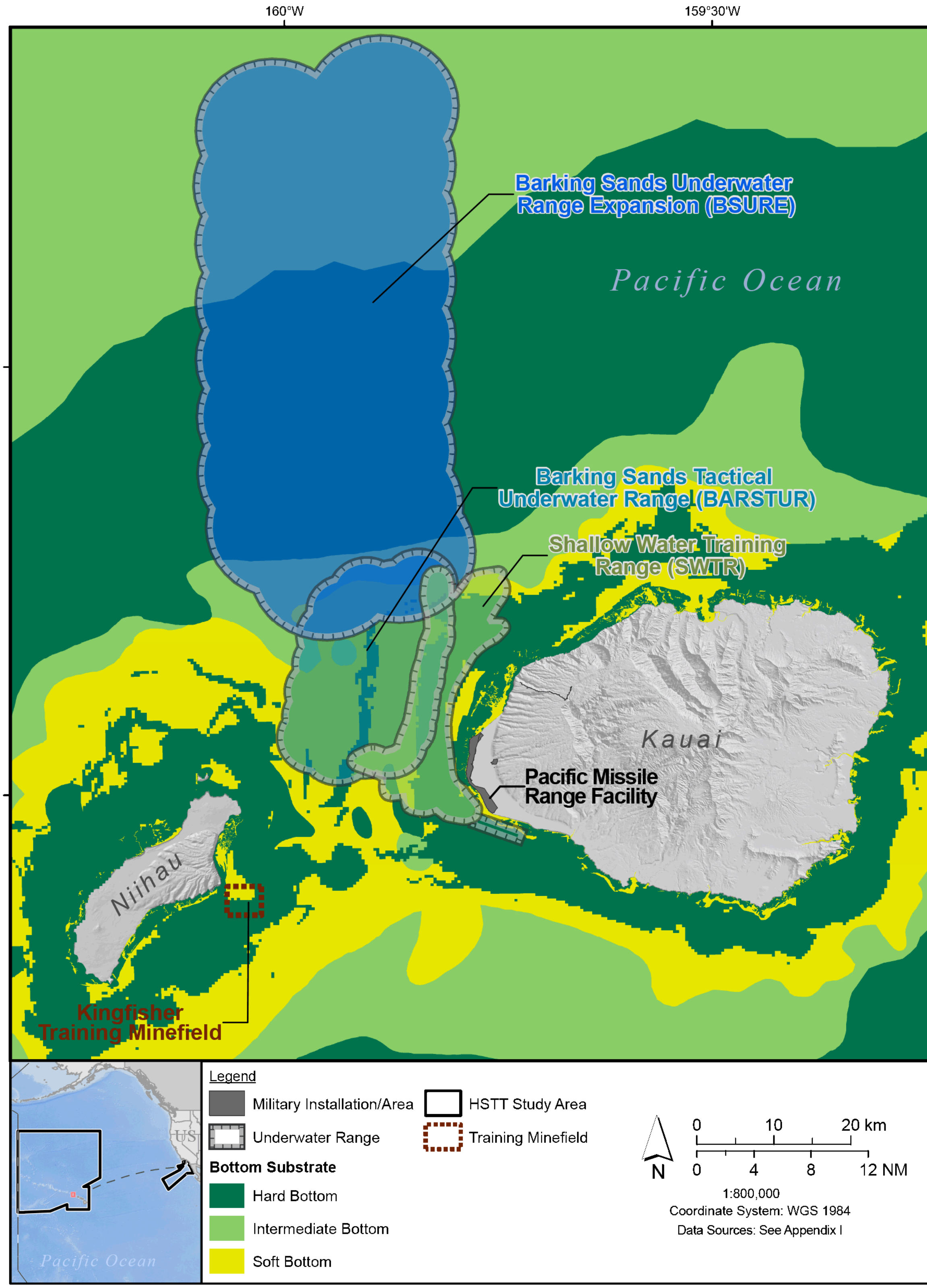


Figure 3.5-3: Bottom Substrate Composition – Islands of Kauai and Niihau

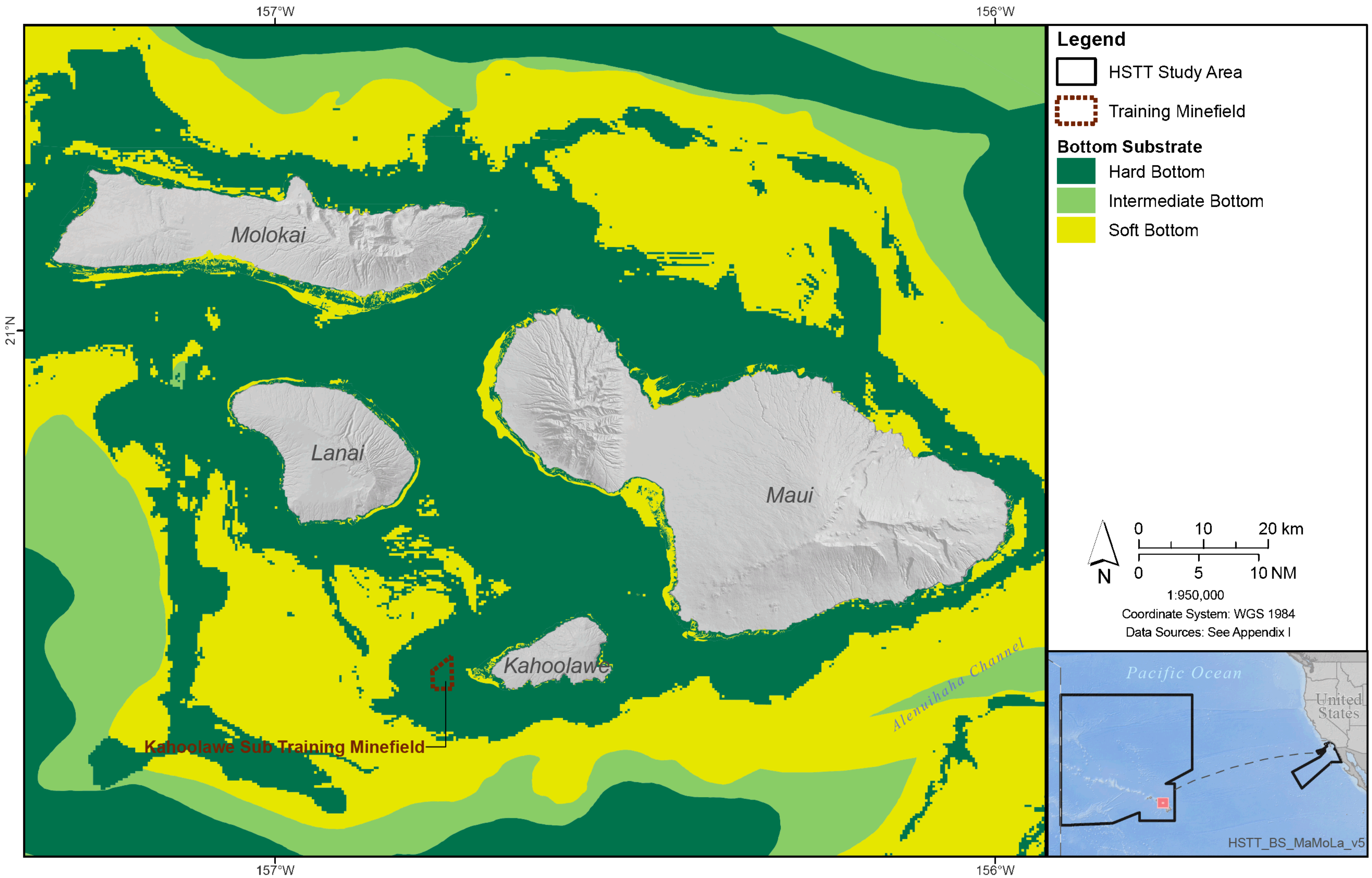


Figure 3.5-4: Bottom Substrate Composition – Maui, Molokai, and Lanai

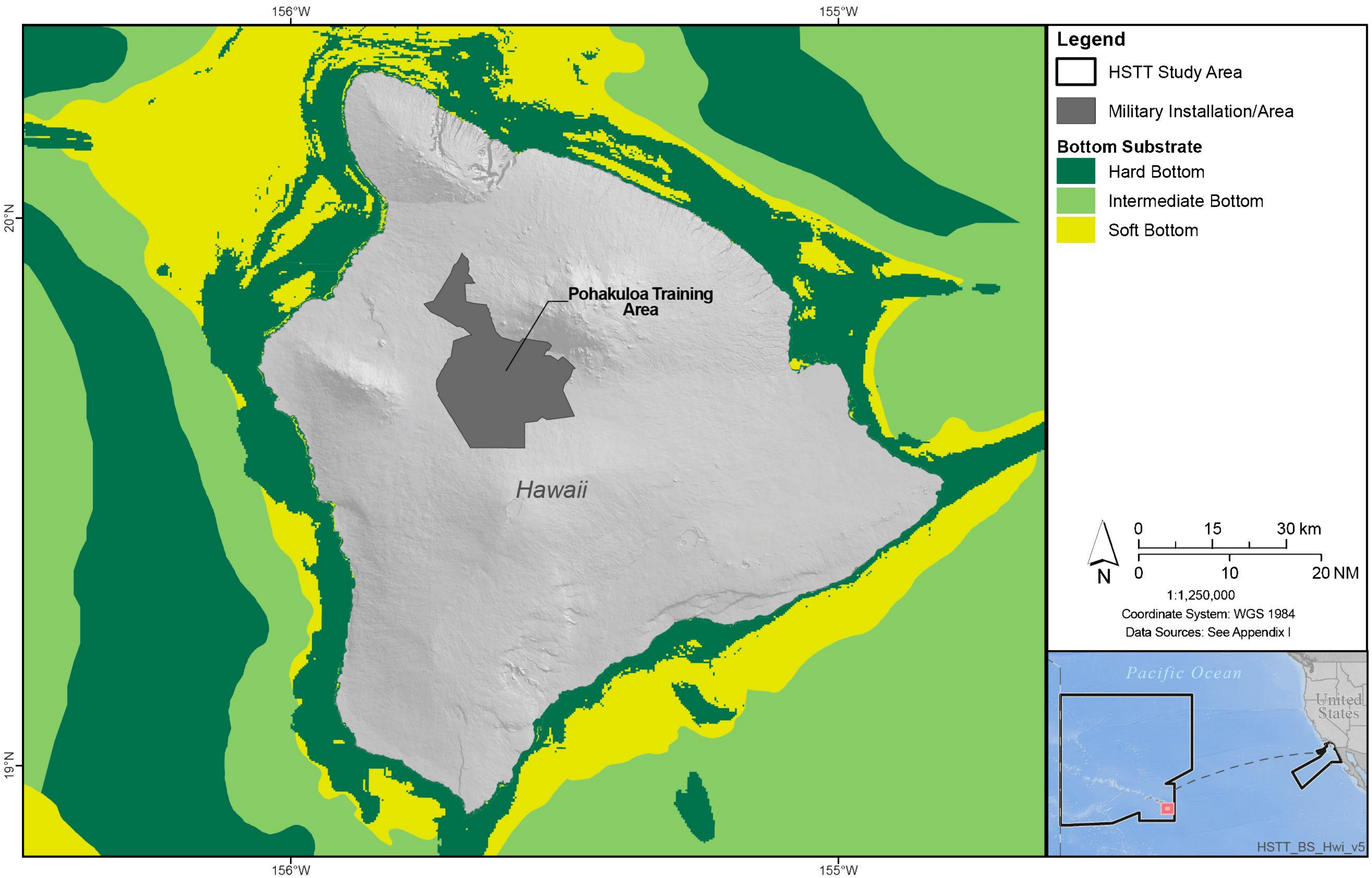


Figure 3.5-5: Bottom Substrate Composition – Hawaii

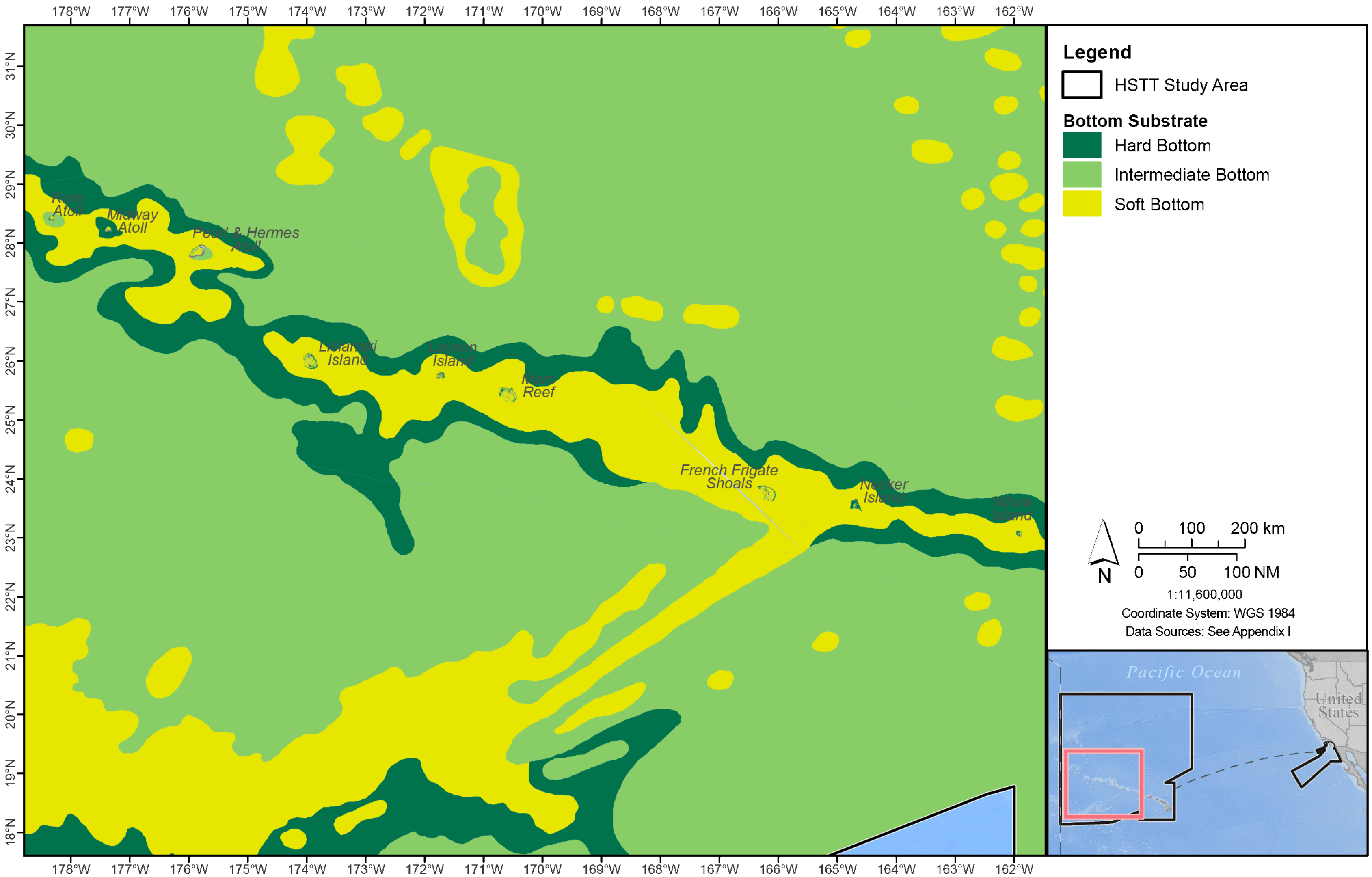


Figure 3.5-6: Bottom Substrate Composition – Northwestern Hawaiian Islands

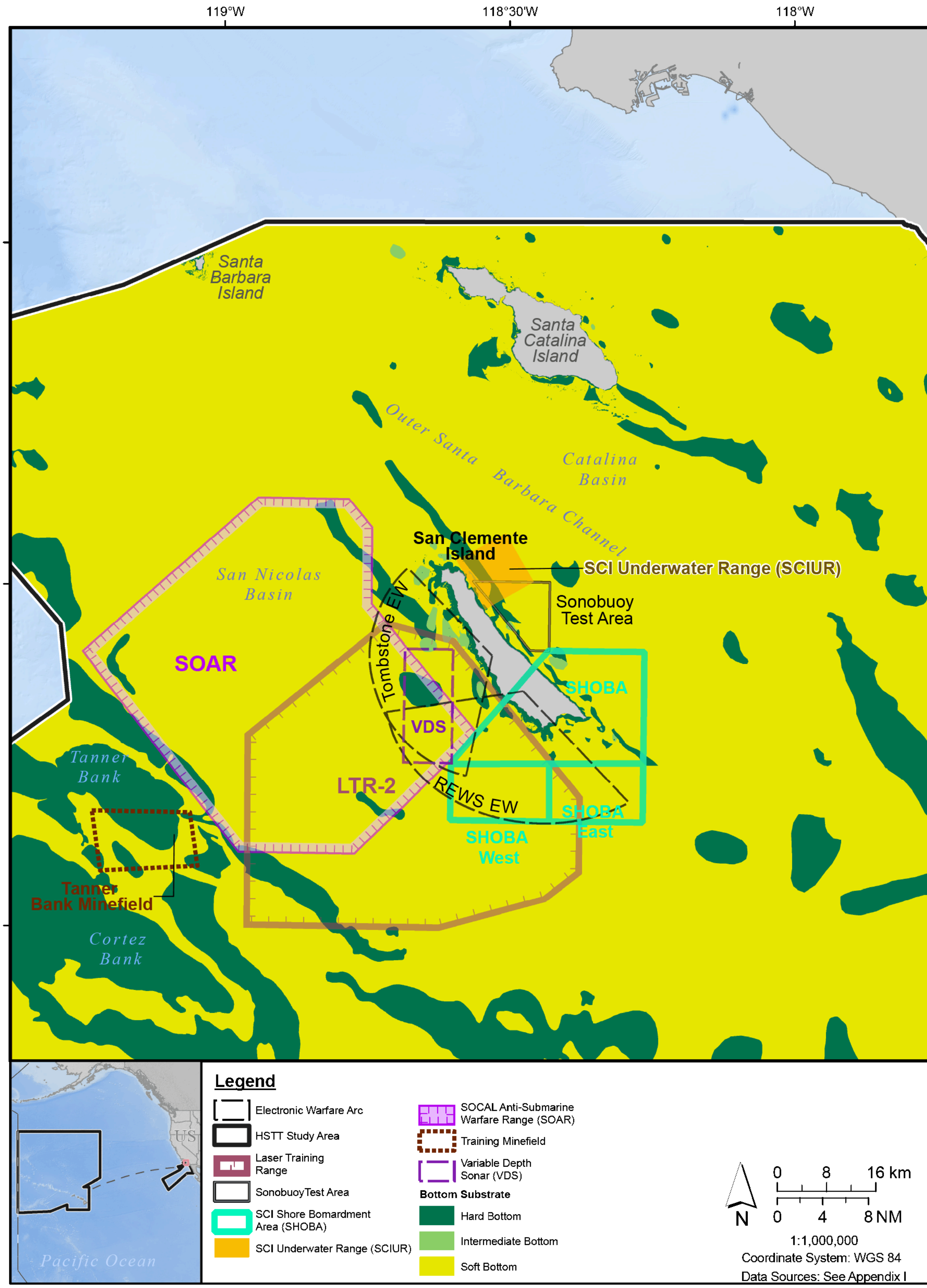


Figure 3.5-7: Bottom Substrate Composition – Southern California Range Complex

Notes: HSTT = Hawaii-Southern California Training and Testing, SOCAL = Southern California, SCI = San Clemente Island

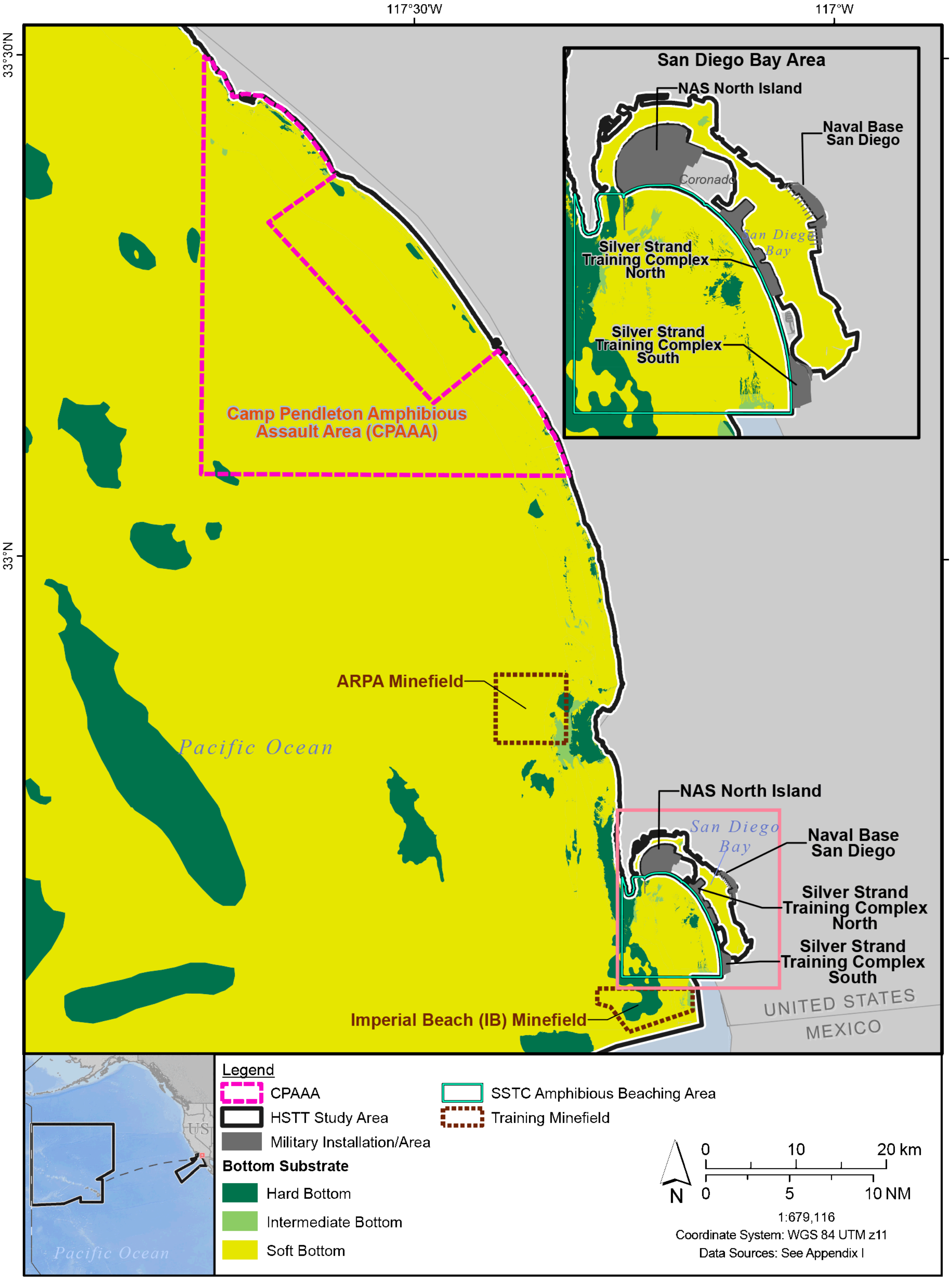


Figure 3.5-8: Bottom Substrate Composition – San Diego Bay

Most of the bottom within the Study Area (over 99 percent) has been mapped (Table 3.5-2). The mapped habitat within the Hawaii Range Complex consists of approximately 5 percent hard bottom, 83 percent intermediate, and 12 percent soft bottom. The Southern California portion of the Study Area consist of 1, 83, and 12 percent hard, intermediate, and soft bottoms, respectively. It should be noted that percent of bottom area does not account for the vertical relief of some hard bottom areas, which contribute disproportionately to hard bottom community biomass.

Table 3.5-2: Percent Coverage of Abiotic Substrate Types in the Study Area

Range Complex	***Percent of Range Complex***					***Total Acres***
	Hard	***Intermediate***	***Soft***	***Unknown***	***Artificial***	
Hawaii Range Complex	5.43%	82.94%	11.63%	0.00%	0.00%	1,971,618,291
Southern California Range Complex	1.33%	83.33%	15.34%	0.00%	0.00%	100,909,604
Grand Total	5.23%	82.96%	11.81%	0.00%	0.00%	2,072,527,894

Source: (U.S. Department of the Navy, 2018)

Soft Bottom

Soft bottom is the dominant habitat type in both the Hawaii and California portions of the Study Area. Overall, however, since only a small portion is mapped reliably and that portion tends to be nearshore, hard and intermediate substrate predominate the mapped areas. Bays and harbors in the Hawaii Range Complex are dominated by fluvial sediment (sediments deposited by rivers and streams) and sediments composed of carbonate grains derived from organisms, such as corals and molluscs. The offshore habitats of the Hawaiian Islands have similar substrate compositions at depths of 300 to 1,600 meters and are dominated by silty sands and clay. At shallow depths, there is an increasing occurrence of rocky outcrops and coral rubble (Miller, 1994). Over 50 percent of the nearshore areas of the Northwestern Hawaiian Islands are considered soft bottom. The abyssal regions, which cover approximately 80 percent of the Hawaii portion of the Study Area, typically consist of fine-grained marine clays (Stephens et al., 1997). However, because this has not been mapped sufficiently for inclusion in the Navy habitat database, it is considered unknown habitat for the purposes of quantitative analysis.

In the California portion of the Study Area, some studies suggested that soft bottom habitat accounts for about 70 to 90 percent of the subtidal habitat (Allen & Pondella, 2006). However, more recent data has shown that soft bottom accounts for only approximately 15 percent of the habitat within the Southern California Range Complex. Sandy sediments are common in nearshore and shelf break portions of the Study Area, while silt, clay, and mud sediments are common between the shelf break and nearshore sand sediments.

The HSTT Transit Corridor follows the most direct route from Hawaii to San Diego. The HSTT Transit Corridor occurs primarily over the abyssal plain, which is an underwater plain that consists of soft bottom habitat, primarily silts and clays.

Intermediate Bottom

Intermediate bottoms occur in both range complexes and the open ocean. However, the bottom types vary across the Study Area. Based on the Navy's habitat classification database, there is no mapped intermediate bottom in the Hawaii Range Complex or the HSTT Transit Lane; however, the Southern California Range Complex is approximately 54 percent intermediate bottom (Figure 3.5-7) and is characterized by at least three studies (U.S. Department of the Navy, 2018). Intermediate habitat again occurs at transitional areas where hard bottom near the islands gives way to the soft bottom habitat in the open ocean.

Hard Bottom

Volcanic rock and consolidated limestone hard bottom habitats account for approximately 5 percent or the habitat in the Hawaii Range Complex. Figure 3.5-1 through Figure 3.5-6 show offshore hard bottom habitats in the Hawaiian Islands. Hard bottom habitat at moderate depths (30 to 100 meters) within the Hawaii Range Complex is relatively abundant. The subtidal regions in the Hawaii Range Complex such as Kaneohe Bay provide extensive solid rock formed from limestone and sand, as well as dead coral, coral rubble, or live coral habitat.

Although the primary habitat of the HSTT Transit Corridor is soft bottom, small portions of hard bottom habitat may lie within that portion of the Study Area. Hard bottom habitat includes rocky outcrops and ridges, banks, and seamounts and other areas of seafloor that are exposed because of ocean currents.

Hard bottom habitats are localized off the Southern California coast, and the potential for transitional intermediate bottom habitats is as well. There is relatively little intermediate bottom habitat in this portion of the Study Area.

Less than 2 percent of the coastal seafloor in Southern California is composed of hard bottom habitat (California Department of Fish and Game, 2009). Shallow hard bottom communities are relatively uncommon and patchy in the Southern California Range Complex. The distribution of hard bottom habitat in the Study Area has not been mapped extensively (Figure 3.5-7) (Whitmire & Clarke, 2007). Hard bottoms are most common offshore of the Southern California portion of California near rocky headlands, along steep shelf areas, and near the shelf break and submarine canyons (Allen & Pondella, 2006).

3.5.2.1.3 Artificial Structures

3.5.2.1.3.1 Description

Man-made structures that are either deliberately or unintentionally submerged underwater create artificial habitats that mimic some characteristics of natural habitats, such as providing hard substrate and vertical relief (Broughton, 2012). Artificial reef habitats have been intentionally created with material from sunken ships, rock and stone, concrete and rubble, car bodies, tires, scrap metal, and various other materials. Artificial habitats also have been created as a result of structures built for other purposes (e.g., breakwaters, jetties, piers, wharves, bridges, oil and gas platforms, fish aggregating devices) or unintentional sinking of vessels (i.e., shipwrecks).

Some artificial structures provide ecological functions similar to natural hard bottom habitats, such as providing attachment substrate for algae and sessile invertebrates, which in turn supports a community of mobile organisms that may forage, shelter, and reproduce there (National Oceanic and Atmospheric Administration, 2007). Other structures may or may not support sessile organisms and only temporarily attract mobile organisms. Factors such as the materials, structural features, and surface area of the artificial structure, as well as local environmental conditions, influence the variety and abundance of sessile organisms that may become established and the relative success of attracting or enhancing local fish populations (Ajemian et al., 2015; Broughton, 2012; Macreadie et al., 2011; Powers et al., 2003; Ross et al., 2016).

Artificial habitats in the Study Area include artificial reefs and shipwrecks. Artificial reefs are designed and deployed to supplement the ecological services provided by coral or rocky reefs. Artificial reefs range from simple concrete blocks to highly engineered structures. Vessels that are unintentionally sunk in the Study Area may be colonized by encrusting and attached marine organisms if there is a larval source and enough nutrition (e.g., detritus) drifting through the water column. Wrecks in the abyssal zone and some locations landward of the deep ocean are typically devoid of encrusting or attached organisms due to the scarcity of drifting food particles in the deep ocean (Nybakken, 1993).

3.5.2.1.3.2 Distribution

Artificial shoreline structures (e.g., piers, wharfs, docks, pilings) in the Study Area occur at or along pierside locations (Section 2.1.4, Pierside Locations and San Diego Bay), including facilities associated with Navy ports and naval shipyards and channels and routes to and from Navy ports in Pearl Harbor and San Diego Bay.

The centroid points of mapped artificial structures in waters of the Study Area are depicted on Figure 3.5-9 and Figure 3.5-10. These include more than 300 mapped points, including mostly shipwrecks (316) and artificial reefs (17) (Table 3.5-3). Not shown on Figure 3.5-9 and Figure 3.5-10 are shipwrecks that are “address restricted” due to status on the National Register of Historic Places and ship hulks sunk during Naval sinking exercises (U.S. Department of the Navy, 2018).

Table 3.5-3: Number of Artificial Structures Documented in the HSTT Study Area

Range Complex	***Artificial Reef***	***Shipwreck***	***Grand Total***
Hawaii Range Complex	5	97	102
Southern California Range Complex	12	219	231
Grand Total	17	316	333

Offshore artificial structures in the Hawaiian portion of the Study Area include shipwrecks, sunken military vessels and aircraft, and artificial reefs. Shipwrecks located near the Island of Hawaii are concentrated along its northwestern coast and within Hilo Bay. Well-documented examples of the numerous submerged structures in the waters surrounding Oahu include the largely intact Sea Tiger, a World War II-era Japanese midget submarine; *Mahi*, a Navy minesweeper/cable layer scuttled off the Waianae Coast; and the YO-257, a Navy yard oiler built in the 1940s that was intentionally sunk off Waikiki in 1989 to create an artificial reef. Major sunken vessels in Pearl Harbor include the USS ARIZONA, the USS UTAH, and the USS BOWFIN, which are listed in the National Register of Historic Places. There may be as many as 60 vessels known lost among the atolls and at least 67 naval aircraft sunk in the Northwestern Hawaiian Islands (National Oceanic and Atmospheric Administration, 2017). At least 14 ships have run aground in the Northwestern Hawaiian Islands since 1957 (Friedlander et al., 2009).

Most artificial structures in the Southern California portion of the Study Area include shipwrecks and artificial reefs. A prominent artificial structure area offshore San Diego County, known as Wreck Alley, includes several types of structures, including six vessels (*El Rey, Ruby E., Shooter’s Fantasy, Strider, Yukon,* and a barge), a P-38 aircraft, old Naval Ocean Systems Center tower, and dumped bridge and roadway materials (California Wreck Divers, 2016). The largest artificial reef in the Study Area was built offshore San Clemente; the Wheeler North Artificial Reef mostly consists of boulder-sized quarry rock deposited in a module design that covers a 174-acre area (Reed et al., 2010).

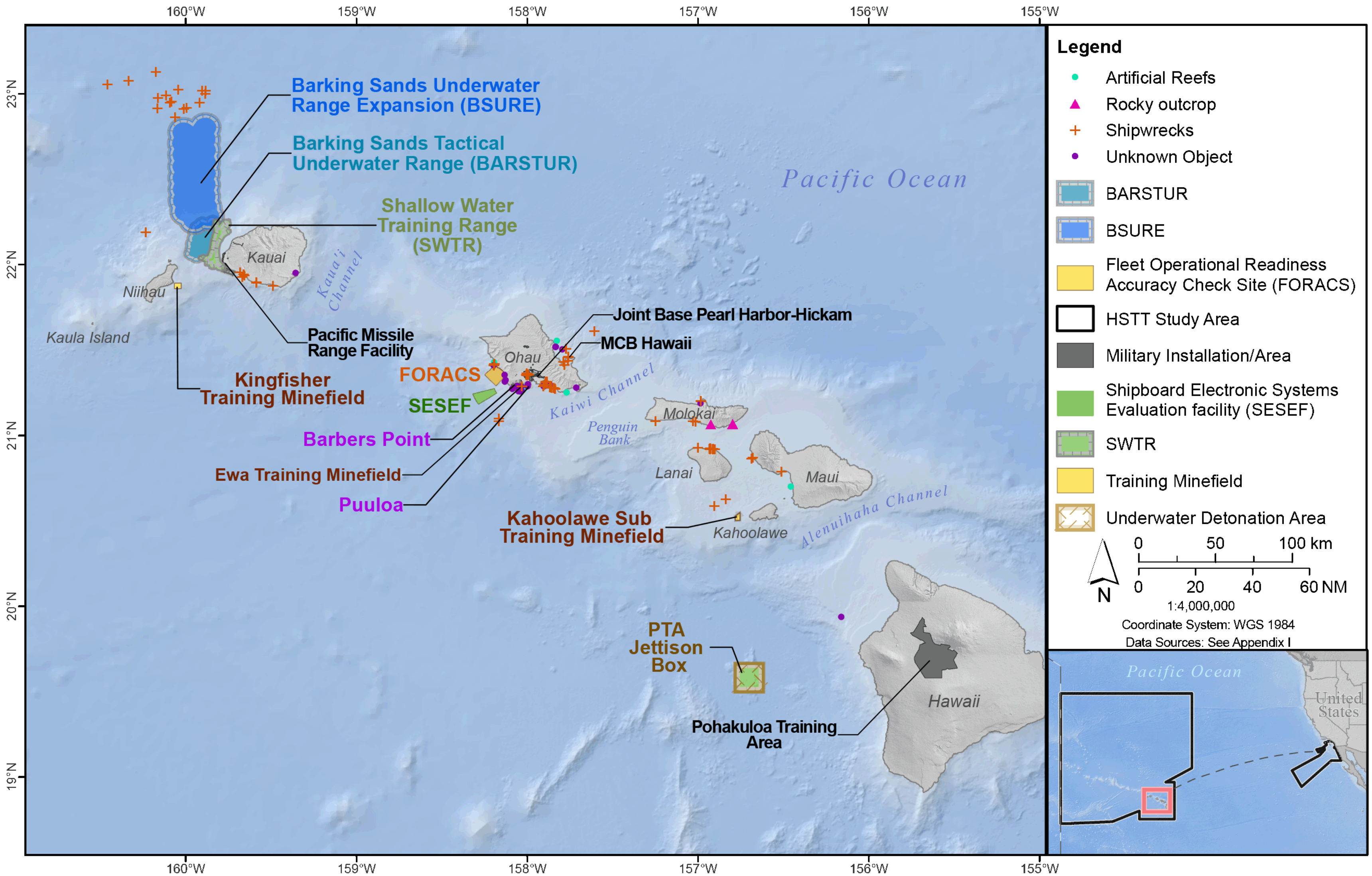


Figure 3.5-9: Map of Artificial Structures in the Hawaii Range Complex

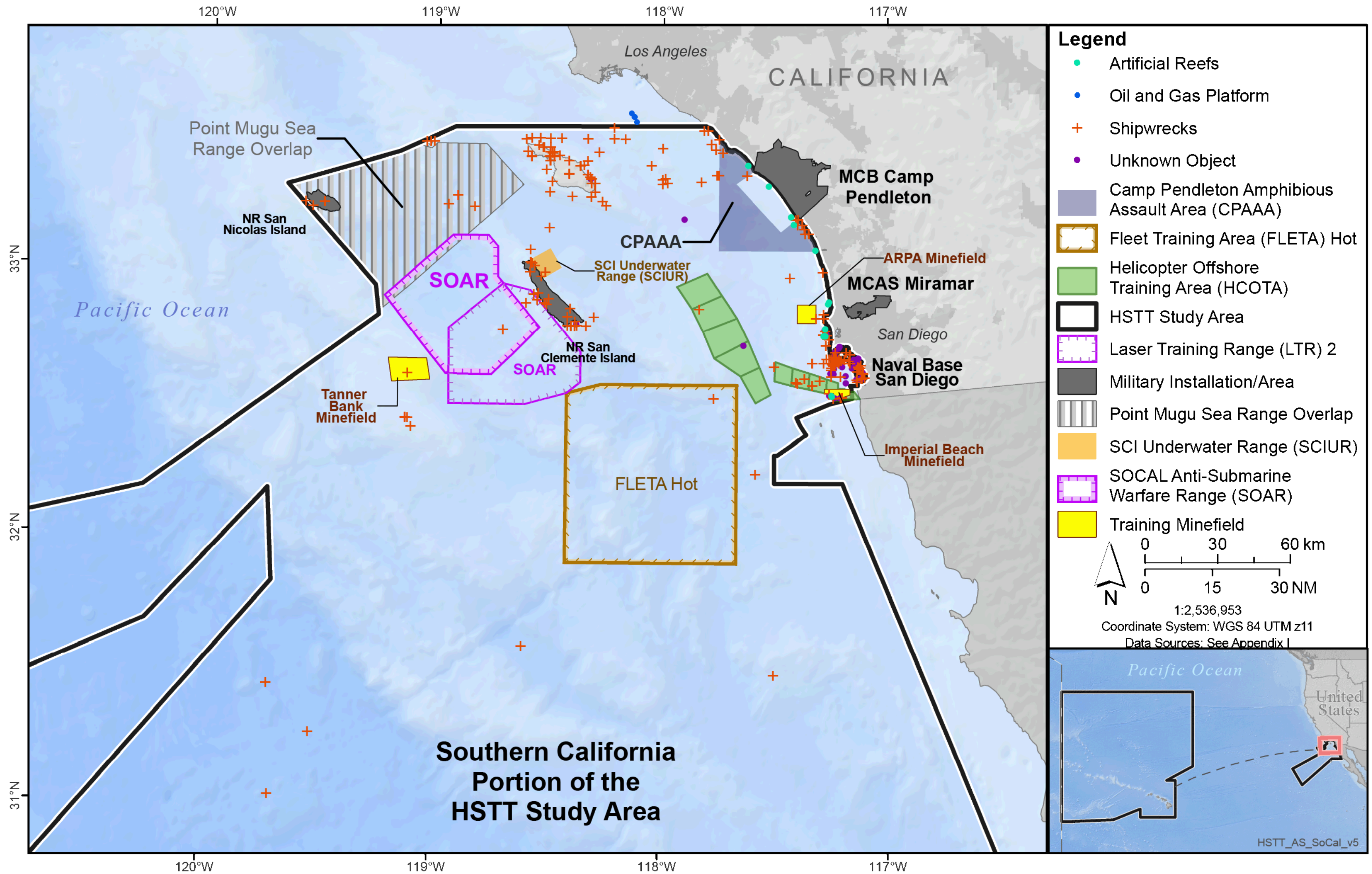


Figure 3.5-10: Map of Artificial Structures in the Southern California Portion of Study Area

Notes: HSTT = Hawaii-Southern California Training and Testing, SOCAL = Southern California

Most artificial reefs in marine waters have been placed and monitored by individual state programs; national and state databases of artificial reefs are not available (National Oceanic and Atmospheric Administration, 2007). A 2001 report identified more than 100 artificial reefs in Southern California (California Department of Fish and Game, 2001a), including some offshore Camp Pendleton, Carlsbad, Bolsa Chica, and Mission Bay (California Department of Fish and Game, 2001a, 2001b). In addition to deploying reefs to enhance fish habitat, California has constructed some artificial reefs specifically to replace or enhance degraded rocky reef and kelp habitat (California Department of Fish and Game, 2009). Artificial reefs installed at Mission Beach, Topanga, and San Mateo Point successfully support mature kelp forests (California Department of Fish and Game, 2009).

Off Southern California, there are 29 oil and gas agreements for operating in state waters, however there are only four offshore oil platforms in state waters off the coast of California (2017). These four platforms offshore of Orange County overlap the northern portion of the Study Area.

In the Insular Hawaii Range Complex, the State of Hawaii manages five artificial reefs, four around Oahu and one on the southern side of Maui (Hawaii Division of Aquatic Resources, 2006). In addition, the State monitors and maintains 34 surface fish aggregating devices and several have been lost or abandoned (University of Hawaii, 2016).

3.5.2.1.4 General Threats

Estuarine and ocean environments worldwide are under pressure from a variety of human activities, such as coastal development, shoreline stabilization, dredging, flood control, and water diversion; destructive fishing practices; offshore energy and resource development and extraction; and global climate change (Boehlert & Gill, 2010; Clark et al., 2016; Clarke et al., 2014; Crain et al., 2009; National Oceanic and Atmospheric Administration Marine Debris Program, 2016). These activities produce a range of physical and chemical stressors on habitats. Primary threats to marine habitats include habitat loss, degradation, or modification. Although stressors may be similar or widespread geographically, their effects on marine habitats are not random or equal. Human activities vary in their spatial distribution and intensity of impact (Halpern et al., 2008). Accordingly, their effects on habitats will vary depending on local differences in the duration, frequency, and intensity of stress; scale of effect; and environmental conditions. Areas where heavy concentrations of human activity co-occur with naval training and testing activities have the greatest potential for cumulative stress on the marine ecosystem (see Chapter 4, Cumulative Impacts, for more information).

3.5.2.1.4.1 Urbanization

Habitat loss and degradation are the primary threats of urbanization. Coastal development has resulted in loss of coastal dune and wetland habitats, modification of shorelines and estuaries, and degradation of water quality (Crain et al., 2009; Lotze et al., 2006). In addition, development has resulted in a proliferation of artificial structure habitats, such as breakwaters, jetties, rock groins, seawalls, oil and gas platforms, docks, piers, wharves, and underwater cables and pipelines, as well as artificial reefs.

Maintenance of coastal infrastructure, ports, and harbors disturbs or modifies intertidal and subtidal habitats, the extent of which varies depending on the type, scale, or frequency of the activity. For example, maintenance has increased the use of shoreline stabilization measures (engineered structures, beach nourishment) to reduce storm-related damages to coastal infrastructure. Flood control or shoreline stabilization measures may have temporary or long-term impacts on beach habitats and may also affect adjacent intertidal and subtidal habitats due to suspended sediment and sedimentation, altered sediment supply and transport dynamics, or creation of artificial substrates (Bacchiocchi &

Airoldi, 2003). Periodic dredging and excavation of sediment is undertaken to maintain navigable channels, tidal exchange, and/or flood control capacity in bays and estuaries. Sediment removal directly disturbs subtidal soft bottom habitat and may indirectly disturb or modify adjacent habitats (Newell et al., 1998). A number of factors may influence maintenance frequency, including sediment characteristics, shoreline and watershed characteristics, oceanographic conditions, and climate.

Tourism is an important economic driver of development in coastal areas and represents an additional stressor in urbanized areas. For example, nearshore coral reefs along the more developed main Hawaiian Islands have been impacted by trampling; damage from divers and swimmers touching, kicking, breaking, sitting, or standing on coral; and improper boat anchoring (Wiener et al., 2009). Within the highly urbanized Southern California portion of the Study Area, human visitation and disturbances impact rocky intertidal (trampling, overturning of rocks, collecting) and sandy beach (mechanical beach grooming) habitats (Dugan et al., 2003; Garcia & Smith, 2014; Murray et al., 1999).

3.5.2.1.4.2 Water Quality

Pollution of marine waters and the accumulation of contaminants in marine sediments pose threats to marine ecosystems, public health, and local economies of coastal regions (Crain et al., 2009). Marine and estuarine water and sediment quality may be influenced by industrial and wastewater discharges, soil erosion, stormwater runoff, vessel discharges, marine construction, and accidental spills. Activities that disturb or remove marine sediments also impact water quality and may alter physical and chemical properties of sediments at and adjacent to the disturbance due to sediment resuspension and sedimentation. Generally, threats to water and sediment quality are greater in waterbodies adjacent to watersheds with substantial urban or agriculture land uses. For more detailed discussion of water quality and potential impacts, see Section 3.2 (Sediments and Water Quality). For more detailed discussion of water quality and potential impacts, see Section 3.2 (Sediments and Water Quality).

3.5.2.1.4.3 Commercial Industries

A variety of commercial development, operations, and activities impact marine habitats and associated organisms (e.g., oil/gas development, telecommunications infrastructure, steam and nuclear power plants, desalinization plants, alternative energy development, shipping and cruise vessels, commercial fishing, aquaculture, and tourism operations) (Crain et al., 2009). Commercial activities are conducted under permits and regulations that require companies to avoid and minimize impacts to marine habitats, especially sensitive hard bottom and biogenic habitats (e.g., coral reefs, shellfish beds, vegetated habitats).

Marine habitats may be directly impacted during marine construction (e.g., cable laying and burial, dredging, pipeline installation, pile driving, work boat anchoring), commercial bottom fishing, and commercial vessel anchoring. Generally, disturbance impacts to soft bottom habitats are temporary; however, there is the potential to degrade the quality of soft bottom habitat for biological resources depending on the extent and frequency of disturbance (Newell et al., 1998). Hard bottom and biogenic habitats are most vulnerable to damage or degradation by commercial industry development and operations. For example, anchors, anchor chains, or cables may damage habitats and abrade and remove organisms from hard bottom surfaces. Commercial fishing use of dredges and bottom trawls impacts bottom topography and sediments and may degrade habitat quality and associated biological communities (Clark et al., 2016). Abandoned or lost fishing gear may alter the structure of abiotic habitats and result in abrasion or entanglement of organisms.

Indirect impacts to habitats may occur from commercial development, discharges, or accidental spills that degrade water or sediment quality. For example, a large artificial reef was constructed off Southern California to partially mitigate impacts to hard bottom and vegetated habitats from cooling water discharges from a nearby nuclear generating station (Reed et al., 2010). Threats associated with impacts to water and sediment quality are further described in Section 3.5.2 (Affected Environment). Accidental spills have the potential to contaminate and degrade marine habitats by coating hard bottom or biogenic substrates as well as mixing into bottom sediments (Hanson et al., 2003). Many factors determine the degree of environmental damage from oil spills, including the type of oil, size and duration of the spill, geographic location, season, and types of habitats and resources present. Effects of oil on bottom habitats include potential long-term impacts on fish and wildlife populations.

3.5.2.1.4.4 Climate Change

All marine ecosystems are vulnerable to the widespread effects of climate change, which include increased ocean temperatures, sea level rise, ocean acidification, and changes in precipitation patterns (Hoegh-Guldberg & Bruno, 2010; Scavia et al., 2002). Rising ocean temperatures will cause waters to expand and ice caps to melt, driving sea levels to rise at various rates depending on geographic location and local environmental conditions. Sea level rise will have the greatest impacts on intertidal and coastal ecosystems that have narrow windows of tolerance to flooding frequency or depth (Crain et al., 2009). Changes in ocean temperatures also are projected to alter ocean circulation, upwelling, and nutrient distribution patterns. It is projected that wet tropical areas and mid-latitude land will experience more frequent and extreme precipitation, which will increase erosion-related sedimentation and runoff to coastal habitats (Keener et al., 2012). The climatic effects will be superimposed upon, and interact with, a wide array of current stresses, including excess nutrient loads, overfishing, invasive species, habitat destruction, and chemical contamination (Scavia et al., 2002).

Beaches and nearshore habitats of Hawaii are considered especially vulnerable to climate change influences such as sea level rise, increased frequency and severity of storms, erosion and sedimentation, and runoff pollution (University of Hawaii, 2014). Southern California beaches and rocky intertidal habitats are particularly vulnerable to sea level rise because development infrastructure limits shoreline retreat along much of the urbanized coastline (Messner et al., 2013). Potential climate change impacts to biogenic habitats are discussed in the vegetated habitats and invertebrate sections of this document.

3.5.2.1.4.5 Marine Debris

In the past decade, marine debris has been increasingly recognized as a key threat to marine ecosystems throughout the world. The Marine Debris Act (33 United States Code 1951 et seq.) defines marine debris as any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment. Artificial substrate that provides hard bottom habitat for marine organisms is discussed in Section 3.4 (Invertebrates). This section focuses on the aspects of marine debris that pose a threat to marine habitats. The accumulation of marine debris can alter and degrade marine habitats through physical damage (e.g., abrasion, shearing); changes to the physical and chemical composition of sediments; and reductions in oxygen and underwater light levels (National Oceanic and Atmospheric Administration Marine Debris Program, 2016). Accumulation or concentration also can degrade the aesthetic appeal of coastal habitats for recreational use, decrease visitation and tourism, require costly cleanups, and impact local economies (Leggett et al., 2014).

3.5.3 Environmental Consequences

The U.S. Navy considered all potential stressors, and the following categories have been analyzed for habitats: explosives and physical disturbance and strikes. This section evaluates how and to what degree the activities described in Chapter 2 (Description of Proposed Action and Alternatives) and Section 3.0.3.3 (Identifying Stressors for Analysis) could impact marine habitats, as defined in this section in the Study Area. Table 2.6-1 through Table 2.6-5 present the proposed training and testing activities (including number of events and locations). General characteristics of all Navy stressors were introduced in Section 3.0.3.3 (Identifying Stressors for Analysis). The stressors vary in intensity, frequency, duration, and location within the Study Area. The stressors analyzed for habitats are:

- **Explosives** (explosives detonated on or near the bottom)
- **Physical Disturbance and Strikes** (vessels and in-water devices, military expended materials, seafloor devices, pile driving)

Impacts of explosives and military expended materials were assessed based on three types of analyses: (1) a conservative scenario assuming all the impacts occur on a single habitat type in an affected area (in a 1-year increment), (2) a more realistic situation in which the impacts are spread proportionally among the habitat types in an affected area (e.g., if hard bottom represents 10 percent of the total habitat within a particular testing or training area or range complex, then 10 percent of the total impact is assumed to occur on hard bottom), and (3) in an increment of 5 years. The most accurate projection would be somewhere between the conservative scenario and proportional distribution, because there are locations in which specific training or testing occurs most frequently within range complexes. However, the number of training and testing activities that occur in the frequently used areas is not limited to a specific percentage as part of the Proposed Action described in this document. The remaining stressors (vessels and in-water devices, seafloor devices, and pile driving) were analyzed based on the number of annual events estimated to occur annually within each range complex. The analysis considers mitigation that the Navy will implement to avoid potential impacts on habitats from explosives and physical disturbance and strike stressors.

3.5.3.1 Acoustic Stressors

Acoustic stressors are not applicable to habitats, due to the lack of hearing capabilities of abiotic habitats, and are not analyzed further in this section.

3.5.3.2 Explosive Stressors

Background

This section analyzes the potential impacts of in-water explosions on or near the bottom resulting from training and testing activities within the Study Area, because those are the only explosives that are expected to potentially impact abiotic substrate.

In-water detonations are used during various mine warfare training activities, surface-to-surface gunnery exercises, air-to-surface gunnery, missile, and bombing exercises, as well as sinking exercises, in-water demolition, and other training activities. Likewise, air-to-surface gunnery, missile, and bombing tests, anti-submarine warfare tracking tests, mine warfare, detection, neutralization tests, and other testing activities also employ in-water explosives. The potential impacts of in-water detonations on marine habitats are assessed according to size of charge (net explosive weight), charge radius, height above the bottom, substrate types in the area, and equations linking all these factors.

Most explosive detonations during training and testing involving the use of high-explosive munitions, including bombs, missiles, and projectile casings, would occur in the air or near the water's surface. Explosives associated with torpedoes, explosive sonobuoys, and explosive mines would occur in the water column; demolition charges could occur near the surface, in the water column, or the ocean bottom. Most surface and water column detonations would occur in waters greater than 3 NM from shore at water depths greater than 100 feet (ft.) and would not be expected to impact the bottom, although mine warfare and demolition detonations could occur in shallow water and typically in a few specific locations within the Study Area. This section only evaluates the impact of explosives placed on the bottom because the physical structure of the water column is not affected by explosions.

An explosive charge would produce percussive energy that would be absorbed and reflected by the bottom. Hard bottom would mostly reflect the energy (Berglind et al., 2009), whereas a crater would be formed in soft bottom (Gorodilov & Sukhotin, 1996). For a specific size of explosive charge, crater depths and widths would vary depending on depth of the charge and substrate type. There is a nonlinear relationship between crater size and depth of water, with relatively small crater sizes in the shallowest water, followed by a spike in size at some intermediate depth, and a decline to an average flat line (indicating similar crater size for all charge weights) at greater depth (Gorodilov & Sukhotin, 1996; O'Keeffe & Young, 1984). Radii of the craters reportedly vary little among unconsolidated substrate types (O'Keeffe & Young, 1984). On substrate types with nonadhesive particles (everything except clay), the effects should be temporary, whereas craters in clay may persist for years (O'Keeffe & Young, 1984). Soft substrate moves around with the tides and currents and depressions are only short-lived (days to weeks) unless they are maintained.

3.5.3.2.1 Impacts from Explosives

3.5.3.2.1.1 Impacts from Explosives Under Alternative 1

Impacts from Explosives Under Alternative 1 for Training Activities

Relevant training activities under Alternative 1 include explosives used during mine countermeasures, mine neutralization using remotely operated vehicles, mine neutralization explosive ordnance disposal, and other activities (see Table 2.6-1 and Appendix B, Activity Stressor Matrices). The number and locations for these stressors under Alternative 1 are provided in Section 3.0.3.3.4.2 (Military Expended Materials). The Navy testing and training areas listed by range complex and acreages of abiotic habitat by type are provided in Appendix F (Military Expended Material and Direct Strike Impact Analyses).

The analysis assumes that half the charges that could be detonated on the bottom during training activities are actually detonated on the bottom. This represents a conservative estimate, as in reality a much lower percentage of detonations is likely to occur directly on the seafloor. The determination of impact is based on estimated crater footprint sizes associated with the following net explosive weight explosions on the bottom: 0.5, 5, 10, 20, and 60 pounds. Note that mitigation measures that may prevent impacts are not included in the quantitative assessment (Chapter 5, Mitigation). Artificial substrate was also included; however, it represented a miniscule percentage of habitat types in the range complexes and procedural mitigation measures would preclude the Navy from conducting explosive in-water detonations on or near artificial structures.

Detonations on the seafloor would result in approximately 1.0 acre and 15.0 acres of impacted habitat per year in the Hawaii Range Complex and Southern California Range Complex, respectively, under the conservative analysis scenario. This represents less than 0.01 percent of hard bottom habitat for each of the range complexes and an even smaller percentage for the other habitat types.

Analysis was conducted in order to determine the proportional impact of explosives training on marine habitats in each of the training areas within the Study Area (Figure 3.5-11). Based on the proportional analysis, total explosive impacts to hard substrate from training activities would be less than 0.5 acre. Impacts to other substrate types would be approximately 13.5, 2.5, and less than 0.5 acres for intermediate, soft, and unknown substrates, respectively. See Appendix F (Military Expended Material and Direct Strike Impact Analyses) for detailed analysis of explosive impacts from training activities in each training area.

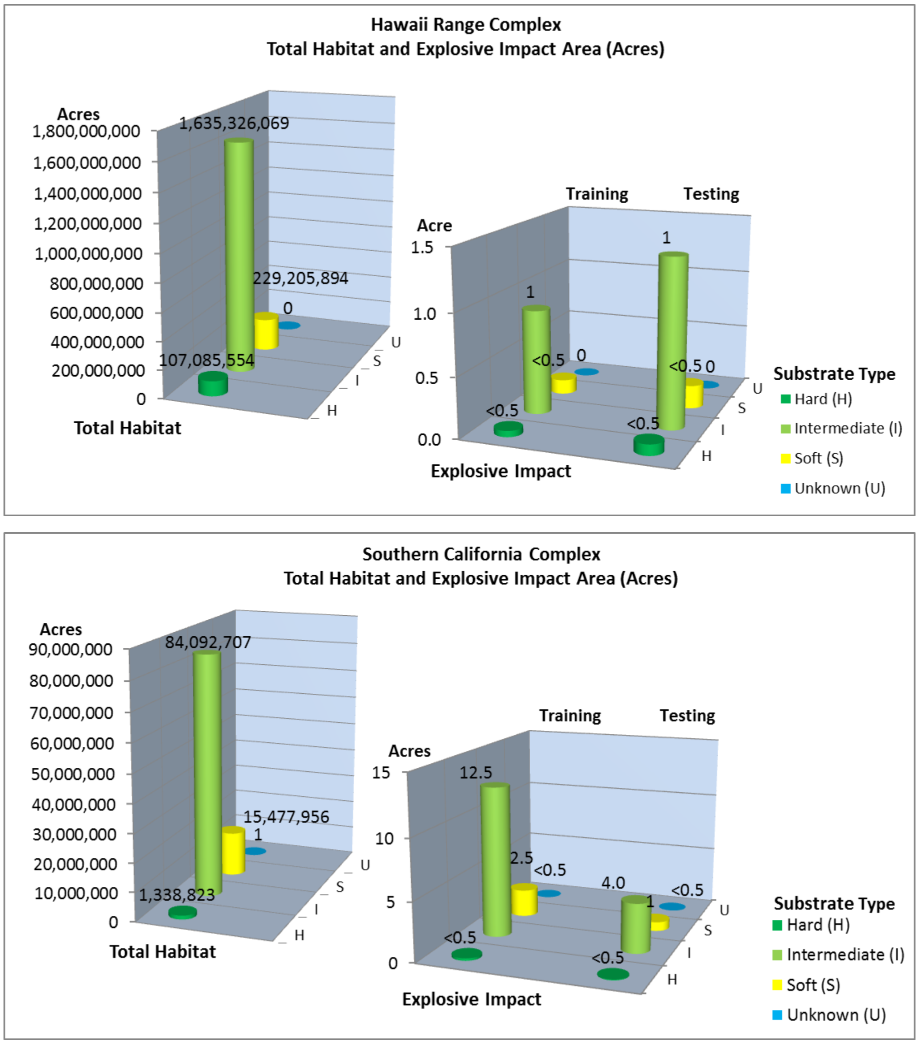


Figure 3.5-11: Alternative 1 – Proportional Impact (Acres) from Explosives by Substrate Type for Training and Testing Compared to Total Habitat Within the Range Complexes Within the Study Area

Analysis was also conducted to evaluate impacts accumulating over the course of a 5-year period. The analysis assumed that all impacts would accumulate. In reality, some habitat would recover over time, as soft substrates are dynamic systems and craters could refill. Areas of hard bottom and other sensitive habitats could be avoided using the Protective Measures Assessment Protocol. The total footprint for impacts from high explosives over a 5-year period, based on a conservative scenario, would be approximately 79.5 acres. Of this, less than 0.01 percent of the total area of each habitat type (hard, intermediate, and soft) would be impacted and less than 0.01 percent of hard bottom. Details of this analysis can be found in Appendix F (Military Expended Material and Direct Strike Impact Analyses).

Under Alternative 1, the areas of bottom habitat in the HSTT Study Area affected annually over a 5-year period by in-water detonations for training activities would be a negligible portion of available bottom habitat. Training events that include seafloor detonations would be infrequent, the percentage of the Study Area affected would be small, and the disturbed areas would likely be soft bottom areas that recover relatively quickly from disturbance. Therefore, in-water explosions under Alternative 1 would mostly be limited to local and short-term impacts on habitat structure in the Study Area.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from explosives on habitats in mitigation areas throughout the Study Area. For example, the Navy will not conduct explosive mine countermeasure and neutralization activities within a specified distance of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks. Mitigation for seafloor resources was not included in the quantitative assessment of habitat impacts; however, it will help the Navy further avoid the potential for impacts on important habitats from certain explosive activities.

Impacts from Explosives Under Alternative 1 for Testing Activities

Various types of explosives are used during training and testing activities. The type, number, and location of activities that use explosives are described in Section 3.0.3.3.2 (Explosive Stressors) and the resulting footprints on bottom habitats are quantified in Appendix F (Military Expended Material and Direct Strike Impact Analyses). The general locations for Alternative 1 activities are listed in Appendix A (Navy Activity Descriptions).

Based on the number of charges and impact areas per year, the conservative scenarios for hard bottom area impacted are less than 1.5 and 5.0 acres in the Hawaii Range Complex and Southern California Range Complex, respectively. This represents less than 0.01 percent of hard bottom habitat for each of the range complexes and an even smaller percentage for the other habitat types.

Additional analysis was conducted in order to determine the proportional impact of explosives testing on marine habitats in each of the range complexes within the Study Area (Figure 3.5-11). Based on the proportional analysis of impacts, total explosive impacts to hard substrate from testing activities would be less than 0.5 acre. Impacts to other substrate types would be approximately 5.5 acres and less than 1.0 acre for intermediate and soft substrates, respectively. See Appendix F (Military Expended Material and Direct Strike Impact Analyses) for detailed analysis of explosive impacts from testing activities in each range complex.

Analysis was also conducted to evaluate impacts accumulating over the course of a 5-year period. The analysis assumed that all impacts would accumulate. In reality, some habitat would recover over time, as soft substrates are dynamic systems and craters could refill. Areas of hard bottom and other sensitive habitats could be avoiding using the Protective Measures Assessment Protocol. The total footprint for impacts from high explosives over a 5-year period, based on a conservative scenario, would be approximately 31 acres. Of this, less than 0.01 percent of the total area of each habitat type (hard, intermediate, and soft) would be impacted. Details of this analysis can be found in Appendix F (Military Expended Material and Direct Strike Impact Analyses).

Under Alternative 1, the areas of bottom habitat in the Hawaii Range Complex and Southern California Range Complex affected annually by in-water detonations for testing activities would be a negligible portion of available bottom habitat. Testing events that include seafloor detonations would be infrequent, the percentage of testing area affected would be small, and the disturbed areas would likely be soft bottom areas that recover relatively quickly from disturbance. Therefore, in-water explosions under Alternative 1 would mostly be limited to local and short-term impacts on habitat structure in the Study Area and consequently would not be significant.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from explosives on habitats in mitigation areas throughout the Study Area. For example, the Navy will not conduct explosive mine countermeasure and neutralization activities within a specified distance of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks. Mitigation for seafloor resources was not included in the quantitative assessment of habitat impacts; however, it will help the Navy further avoid the potential for impacts on important habitats from certain explosive activities.

3.5.3.2.1.2 Impacts from Explosives Under Alternative 2

Impacts from Explosives Under Alternative 2 for Training Activities

Relevant training activities included in Alternative 2 would be the same as under Alternative 1 (see Table 2.6-1). Explosive activities would be the same as those analyzed under Alternative 1 within the Hawaii Range Complex and Southern California Range Complex. The general locations for these activities under Alternative 2 are listed in Appendix A (Navy Activity Descriptions) and are shown on Figure 3.5-1 through Figure 3.5-8. The Navy testing and training areas listed by range complex and acreages of abiotic habitat by type are provided in Appendix F (Military Expended Material and Direct Strike Impact Analyses).

Training events that include bottom-laid in-water explosions are infrequent and the percentage of training area affected would be less than 0.01 percent of the total training area within the range complex, so the bottom substrates impacted would be a negligible portion of available bottom habitat and disturbed areas would be expected to recover their previous structure. Therefore, in-water explosions under Alternative 2 would mostly be limited to local and short-term impacts on habitat structure in the Study Area.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from explosives on habitats in mitigation areas throughout the Study Area. For example, the Navy will not conduct explosive mine countermeasure and neutralization activities within a specified distance of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks. Mitigation for seafloor resources was not included in the quantitative assessment of habitat impacts; however, it will help the Navy further avoid the potential for impacts on important habitats from certain explosive activities.

Impacts from Explosives Under Alternative 2 for Testing Activities

Relevant testing activities included in Alternative 2 would be nearly the same as under Alternative 1, though the number of in-water detonations that would occur within the Study Area would be slightly increased in the Southern California Range Complex. Impacts from other activities would remain the same as discussed above under Alternative 1 impacts from explosives for testing. The general locations for these activities under Alternative 2 are listed in Appendix A (Navy Activity Descriptions). The Navy testing and training areas are listed by range complex and acreages of abiotic habitat by type and provided in Appendix F (Military Expended Material and Direct Strike Impact Analyses).

Based on the number of charges and impact areas per year, the conservative scenarios for hard bottom are 1.5 and 6.5 acres of impacted habitat per year in the Hawaii Range Complex and Southern California Range Complex, respectively. This represents less than 0.01 percent of hard, intermediate, and soft bottom habitat in each area.

Analysis was conducted in order to determine the proportional impact of explosives testing on marine habitats in each of the testing areas within the Study Area (Figure 3.5-12). Based on the proportional analysis, total explosive impacts to hard substrate from testing activities would be less than 0.5 acre. Impacts to other substrate types would be approximately 5.5 and less than 1.0 acres for intermediate and soft substrates, respectively. See Appendix F (Military Expended Material and Direct Strike Impact Analyses) for detailed analysis of explosive impacts from testing activities in each testing area.

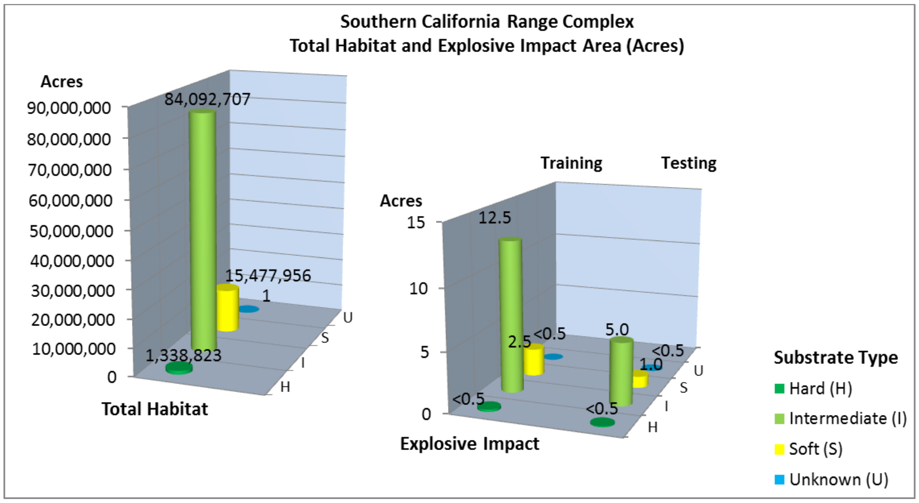


Figure 3.5-12: Alternative 2 – Proportional Impact (Acres) from Explosives by Substrate Type for Training and Testing Compared to Total Vulnerable Habitat Within the Study Area

Note: Only the range complex with a different proportional impact for Alternative 2 is shown here; other training and testing areas have the same impact for Alternative 2 as Alternative 1 (Figure 3.5-11)

Analysis was also conducted to evaluate impacts accumulating over the course of a 5-year period. The analysis assumed that all impacts would accumulate. In reality, some habitat would recover over time, as soft substrates are dynamic systems and craters could refill. Areas of hard bottom and other sensitive habitats could be avoiding using the Protective Measures Assessment Protocol. The total footprint for impacts from high explosives over a 5-year period, based on a conservative scenario, would be approximately 38.0 acres. However, proportional impacts would still affect less than 0.01 percent of each habitat type (hard, intermediate, soft, and unknown, respectively). Details of this analysis can be found in Appendix F (Military Expended Material and Direct Strike Impact Analyses).

Under Alternative 2, the areas of bottom habitat in the Hawaii Range Complex and Southern California Range Complex affected annually by in-water detonations for testing activities would be a negligible portion of available bottom habitat (less than 0.01 percent annually). Testing events that include seafloor detonations would be infrequent and the percentage of testing area affected would be small, and the disturbed areas would likely be soft bottom areas that recover relatively quickly from disturbance. Therefore, in-water explosions under Alternative 2 would mostly be limited to local and short-term impacts on marine habitat structure in the Study Area.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from explosives on habitats in mitigation areas throughout the Study Area. For example, the Navy will not conduct explosive mine countermeasure and neutralization activities within a specified distance of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks. Mitigation for seafloor resources was not included in the quantitative assessment of habitat impacts; however, it will help the Navy further avoid the potential for impacts on important habitats from certain explosive activities.

3.5.3.2.1.3 Impacts from Explosives Under the No Action Alternative

Impacts from Explosives Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various explosive stressors (e.g., in-water detonations occurring on or near the seafloor) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.5.3.3 Energy Stressors

Energy stressors are not applicable to habitats, since activities that include the use of energy-producing devices are typically conducted at or near the surface of the water and would not impact bottom habitats. Therefore, they are not analyzed further in this section.

3.5.3.4 Physical Disturbance and Strike Stressors

This section analyzes the potential impacts of the various types of physical disturbance and strike stressors resulting from the Navy training and testing activities within the Study Area. This analysis includes the potential impacts of (1) vessels and in-water devices, (2) military expended materials, (3) seafloor devices, and (4) pile driving.

Impacts from physical disturbances or strikes resulting from Navy training and testing activities on biota inhabiting soft bottom (habitat for seagrasses, clams, etc.) and hard bottom (habitat for hard corals, seaweed, sponges, etc.) substrates are discussed in Section 3.3 (Vegetation) and Section 3.4 (Invertebrates). Potential impacts to the underlying substrates (soft, intermediate, hard, or artificial) are analyzed here.

3.5.3.4.1 Impacts from Vessels and In-Water Devices

Vessels conducting training and testing activities in the Study Area include large ocean-going ships and submarines typically operating in waters deeper than 100 m but also occasionally transiting inshore waters from ports and through the operating areas. Training and testing activities also include smaller vessels operating in inshore waters, typically at higher speeds (greater than 10 knots). Vessels used for training and testing activities range in size from small boats (less than 40 ft.) to nuclear aircraft carriers (greater than 980 ft.) Table 3.0-15 lists representative types of vessels, including amphibious warfare vessels, used during training and testing activities. Towed mine warfare and unmanned devices are much smaller than other Navy vessels, but would also disturb the water column near the device. Some activities involve vessels towing in-water devices used in mine warfare activities. The towed devices attached to a vessel by cables are smaller than most vessels, and are not towed at high speeds. Some vessels, such as amphibious vehicles, would intentionally contact the seafloor in the surf zone.

Vessels, in-water devices, and towed in-water devices could either directly or indirectly impact any of the habitat types discussed in this section, including soft and intertidal shores, soft and hard bottoms, and artificial substrates. In addition, a vessel or device could disturb the water column enough to stir up bottom sediments, temporarily increasing the local turbidity. The shore and nearshore environment is typically very dynamic because of its constant exposure to wave action and cycles of erosion and deposition. Along high-energy shorelines like ocean beaches, these areas would be reworked by waves and tides shortly after the disturbance. Along low-energy shoreline in sheltered inshore waters, the force of vessel wakes can result in elevated erosion and resuspension of fine sediment (Zabawa & Ostrom, 1980). In deeper waters where the tide or wave action has little influence, sediments suspended into the water column would eventually settle. Sediment settlement rates are highly dependent on grain size. Disturbance of deeper bottom habitat by vessels or in-water devices is possible where the propeller wash interacts with the bottom. However, most vessel transiting in shallow, nearshore waters is confined to navigation channels where bottom disturbance only occurs with the largest vessels. An exception would be for training and testing activities that occur in shallow, nearshore environments. Turbidity caused by vessel operation in shallow water, propeller scarring, and vessel grounding could impact habitats in shallow-water areas. In addition, physical contact with hard bottom areas can cause structural damage to the substrate. However, direct impacts to the substrate are typically avoided because they could slow or damage the vessel or in-water device. These disturbances would not alter the overall nature of the sediments to a degree that would impair their function as habitat. The following alternatives analysis specifies where these impacts could occur in terms of number of events with vessel movement or in-water devices training/testing in different habitat areas.

3.5.3.4.1.1 Impacts from Vessels and In-Water Devices Under Alternative 1

Impacts from Vessels and In-Water Devices Under Alternative 1 for Training Activities

As indicated in Sections 3.0.3.3.4.1 (Vessels and In-Water Devices), the majority of the training activities include vessels. These activities could be widely dispersed throughout the Study Area but would be more concentrated near naval ports, piers, and ranges. Navy training vessel traffic would occur in the Hawaii Range Complex, southern California portion of the Study Area, and HSTT Transit Corridor. Amphibious landings would be restricted to designated beaches within the Hawaii Range Complex, Southern California Range Complex, and Silver Strand Training Complex.

Because of the nature of vessel operation and intentional avoidance of bottom strikes, most shore and bottom habitats would not be exposed to vessel strikes, but could be exposed to vessel disturbance by propeller wash. Groundings would be accidental and are rare. Amphibious vehicles are an exception, but only designated beaches that are naturally resilient to disturbance are used. Therefore, while vessels may affect shore and bottom habitats, adverse impacts are not likely.

Shallow water habitats within the Study Area would have a very small potential to be exposed to vessel strikes. Vessels would pose no risk to habitats in the open ocean although, in coastal waters, currents from large vessels may cause resuspension of sediment. Vessels travelling at high speeds would generally pose more of a risk through propeller action in shallow waters.

With the exception of amphibious operations, vessel disturbance and strikes affecting habitats would be extremely unlikely. Shallow-water vessels typically operate in defined boat lanes with sufficient depths to avoid propeller or hull strikes of bottom habitats. However, for some inshore training activities the training areas outside of navigation channels may not have sufficient depth to prevent contact with the bottom or resuspension of sediments.

The direct impact of vessels on bottom habitats is restricted to amphibious training beaches whereas the indirect impact of propeller wash and wakes from vessels or in-water devices could impact shallow-water training areas and sheltered shoreline habitats. However, the bottom disturbance associated with propeller wash represents only a temporary resuspension of sediment in the shallowest portion of training areas. The effect of surface wakes is limited to high speed training along relatively sheltered shorelines and is likely indistinguishable from the effect of other vessel wakes or storms in waters open to the public. Sheltered waters restricted to the public are typically harbors where no-wake speeds are enforced.

There is very little likelihood of impacts to habitats due to in-water devices because the devices are not expected to contact the seafloor during training activities, because operational procedures typically avoid shallow areas and intentionally avoid vessels or devices contacting the bottom, and exposures would be localized, temporary, and would cease with the conclusion of the activity.

Impacts from Vessels and In-Water Devices Under Alternative 1 for Testing Activities

As indicated in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), Navy vessel movements and in-water device usage for testing activities would be similar to those described previously under training activities.

Because of the nature of vessel and in-water device operation and intentional avoidance of bottom strikes, most habitat would not be exposed to vessel or in-water device direct strikes.

The impact of vessels and in-water devices on marine habitats would be inconsequential, because the footprint of potential impact is extremely small relative to the overall availability of habitat, operational procedures typically avoid shallow areas and intentionally avoid vessels or devices contacting the bottom, and exposures would be localized, temporary, and would cease with the conclusion of the activity.

3.5.3.4.1.2 Impacts from Vessels and In-Water Devices Under Alternative 2

Impacts from Vessels and In-Water Devices Under Alternative 2 for Training Activities

As indicated in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), Navy vessel movements and in-water device usage under Alternative 2 would be similar to those described previously under Alternative1 training activities, although the overall number of vessel operations would be slightly increased due to more active hull-mounted sonar operations.

Because of the nature of vessel and in-water device operation and intentional avoidance of bottom strikes, most habitat would not be exposed to vessel or in-water device direct strikes. Amphibious landings are an exception, but these activities are conducted in designated areas that have been historically used for this type of activity and are generally devoid of any quality habitat.

The impact of vessels and in-water devices on marine habitats would be inconsequential because the footprint of potential impact is extremely small relative to the overall availability of habitat, operational procedures typically avoid shallow areas and intentionally avoid vessels or devices contacting the bottom, and exposures would be localized, temporary, and would cease with the conclusion of the activity.

Impacts from Vessels and In-Water Devices Under Alternative 2 for Testing Activities

As indicated in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), Navy vessel movements and in-water device usage for testing activities under Alternative 2 would be similar to those described previously under Alternative 2 training activities.

Because of the nature of vessel and in-water device operation and intentional avoidance of bottom strikes, most habitats would not be exposed to vessel or in-water device direct strikes. Amphibious landings are an exception; however, they are not included in testing activities.

The impact of vessels and in-water devices on marine habitats would be inconsequential because the footprint of potential impact is extremely small relative to the overall availability of habitat, operational procedures typically avoid shallow areas and intentionally avoid vessels or devices contacting the bottom, and exposures would be localized, temporary, and would cease with the conclusion of the activity.

3.5.3.4.1.3 Impacts from Vessels and In-Water Devices Under the No Action Alternative

Impacts from Vessels and In-Water Devices Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various physical disturbance and strike stressors (e.g., vessels and in-water devices) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.5.3.4.2 Impacts from Aircraft and Aerial Targets

Impacts from Aircraft and Aerial Targets are not applicable to habitats because aircraft and aerial targets would not contact or otherwise affect shore or bottom habitats and are not analyzed further in this section.

3.5.3.4.3 Impacts from Military Expended Materials

This section analyzes the potential for physical disturbance to marine substrates from the following categories of military expended materials: (1) non-explosive practice munitions, (2) fragments from high-explosive munitions, and (3) expended materials other than munitions, such as sonobuoys, expendable targets, and ship hulks. Note that expended materials do not include materials that are recovered or categorized as in-water or seafloor devices. Areas expected to have the greatest amount of expended materials are the Hawaii Range Complex and Southern California Range Complex. For a discussion of the types of activities that use military expended materials, where they are used, and how many events would occur under each alternative, see Table 2.6-1 through Table 2.6-5. Military expended materials have the potential to physically disturb marine substrates to the extent that they impair the substrate's ability to function as a habitat. These disturbances can result from several sources, including the impact of the expended material contacting the seafloor and moving around, the covering of the substrate by the expended material, or alteration of the substrate from one type to another.

The potential for military expended materials to physically impact marine substrates as they come into contact with the seafloor depends on several factors. These factors include, but are not limited to, the size, shape, type, density, and speed of the material through the water column; the amount of the material expended; the frequency of training or testing; water depth, water currents, or other disturbances; and the type of substrate. Most of the kinetic energy of the expended material, however, is dissipated within the first few feet of the object entering the water causing it to slow considerably by the time it reaches the substrate. Because the damage caused by a strike is proportional to the force of the strike, slower speeds result in lesser impacts. Due to the water depth at which most training and testing events take place, a direct strike on either hard bottom or artificial structures (e.g., artificial reefs and shipwrecks) is unlikely to occur with sufficient force to damage the substrate. In softer substrates (e.g., sand, mud, silt, clay, and composites), the impact of the expended material coming into contact with the seafloor, if large enough and striking with sufficient momentum, may result in a depression and a localized redistribution of sediments as they are temporarily suspended in the water column. There may also be redistribution of unconsolidated sediment in areas with sufficient flow to move the sediment, creating a pattern of scouring on one side of the material and deposition on the other.

During Navy training and testing, countermeasures such as flares and chaff are introduced into marine habitats. These types of military expended materials are not expected to impact marine habitats as strike stressors, given their smaller size and low velocity compared to projectiles, bombs, and missiles.

Another potential physical disturbance that military expended materials could have on marine substrates would be to cover them or to alter the type of substrate and, therefore, its function as habitat. The majority of military expended materials that settle on hard bottoms or artificial substrates, while covering the seafloor, may serve a similar habitat function as the substrate it is covering by providing a hard surface on which organisms can attach (Figure 3.5-13 and Figure 3.5-14). Similarity in attached organisms over the long term depends on similarity in structural features (Perkol-Finkel et al., 2006; Ross et al., 2016), fine surface texture, and mineral content (Davis, 2009). Natural hard bottom and artificial structures of a similar shape will eventually have similar communities of attached organisms if they have similar fine texture and mineral content. However, the smooth surface texture of intact military expended materials and lack of mineral content suggests a difference in species composition and associated functions. An exception would be expended materials, like the decelerators/parachutes utilized to deploy sonobuoys, lightweight torpedoes, expendable mobile anti-submarine warfare training targets, and other devices from aircraft, which would not provide a hard surface for colonization. In these cases, the hard bottom or artificial structure covered by the expended material would not be physically damaged, but would have an impaired ability to function as a habitat for colonizing or encrusting organisms. There is potential for these items to drift over shallow-water or deep-sea coral habitats.

Most military expended materials that settle on soft bottom habitats, while not damaging the actual substrate, would inhibit the substrate's ability to function as a soft-bottom habitat by covering it with a hard surface. This would effectively alter the substrate from a soft surface to a hard structure and, therefore, would alter the habitat to be more suitable for organisms more commonly found associated with hard bottom environments (U.S. Department of the Navy, 2010, 2011). Expended materials that settle in the shallower, more dynamic environments of the continental shelf would likely be eventually covered over by sediments due to currents and other coastal processes or encrusted by organisms. Depending on the substrate properties and the hydrodynamic characteristics of the area, military

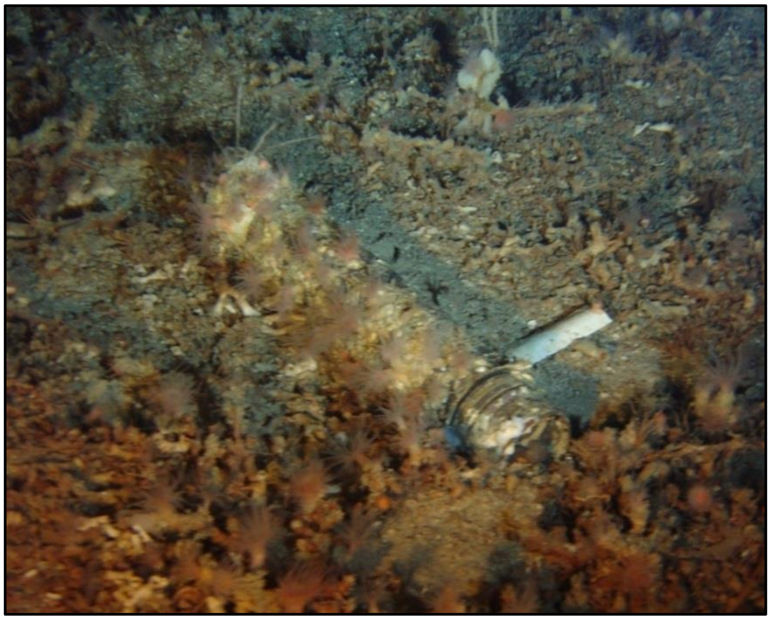


Figure 3.5-13: A Marine Marker Observed in an Area Dominated by Coral Rubble on the Continental Slope

Note: Observed at approximately 350 meters in depth and 60 nautical miles east of Jacksonville, Florida. Of note is the use of the smoke float as a colonizing substrate for a cluster of sea anemones (U.S. Department of the Navy, 2010).

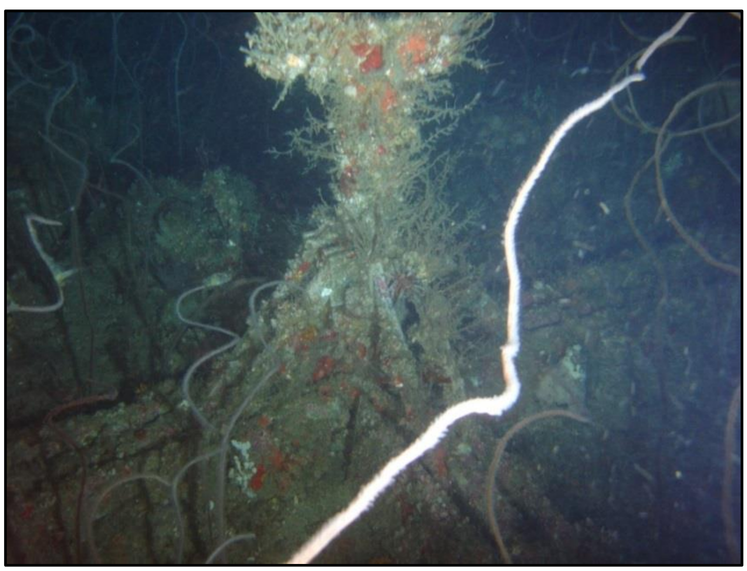


Figure 3.5-14: An Unidentified, Non-Military Structure on Hard Bottom

Note: Observed on the ridge system that runs parallel to the shelf break at approximately 80 meters in depth and 55 nautical miles east of Jacksonville, Florida. Of note is that encrusting organisms and benthic invertebrates readily colonize the artificial structure to a similar degree as the surrounding rock outcrop (U.S. Department of the Navy, 2010).

expended materials may become buried rather quickly while in other areas they may persist on the surface of the seafloor for a more extended time. The offshore portion of the continental shelf experiences more sediment redistribution from oceanic currents (e.g., California Stream) than distant surface waves. The effect of oceanic currents on sediment redistribution diminishes seaward of the continental shelf break: sediment along the continental slope experiences very little reworking from surface currents and waves. In the deeper waters of the continental slope and beyond where currents do not play as large of a role, expended materials may remain exposed on the surface of the substrate with minimal change for extended periods (Figure 3.5-15).

Whereas the impacts will accumulate somewhat through successive years of training and testing, some portion of the expended material will sink below the surface of shifting soft bottom habitat or become incorporated into natural hard bottom before crumbling into inorganic particulates. This will be the fate of military expended materials with a density greater than or equal to that of the underlying substrate (e.g., metal, cement, sand). Constituents of military expended materials that are less dense than the underlying substrate (e.g., fabric, plastic) will likely remain on the surface substrate after sinking. In this case, the impact on substrate as a habitat is likely temporary and minor due to the mobility of such materials (refer to living resources sections for more information on the entanglement and ingestion risk posed by plastic and fabric constituents of military expended materials).

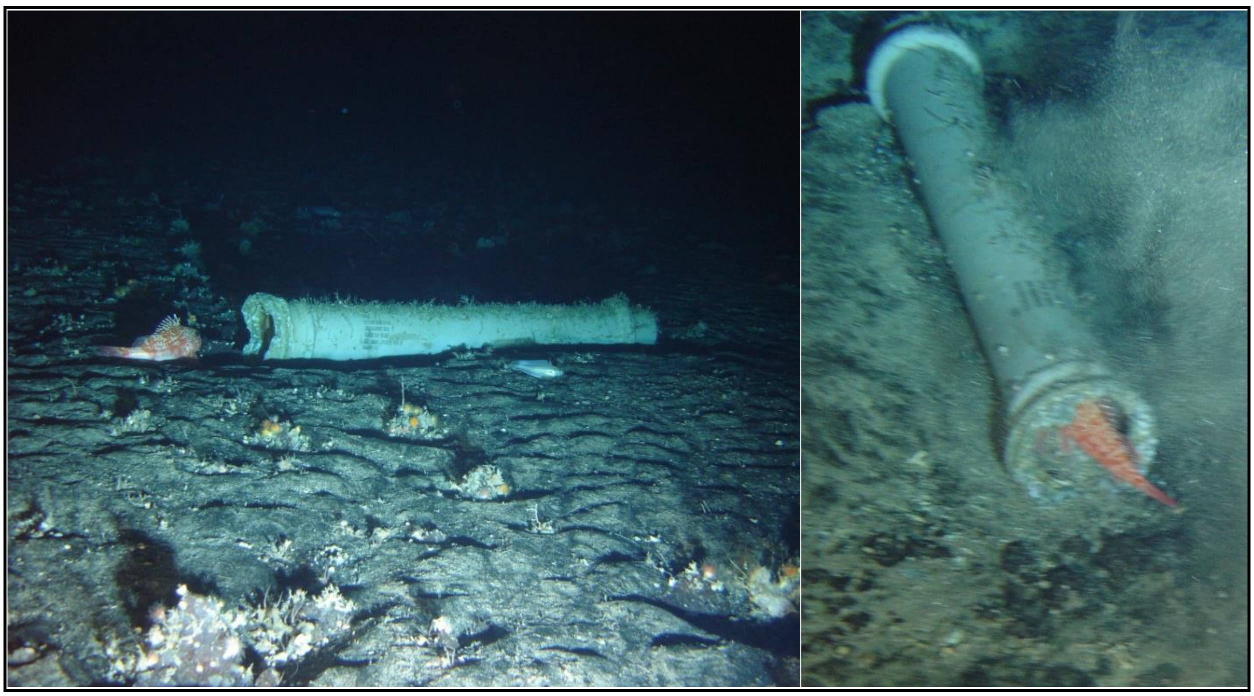
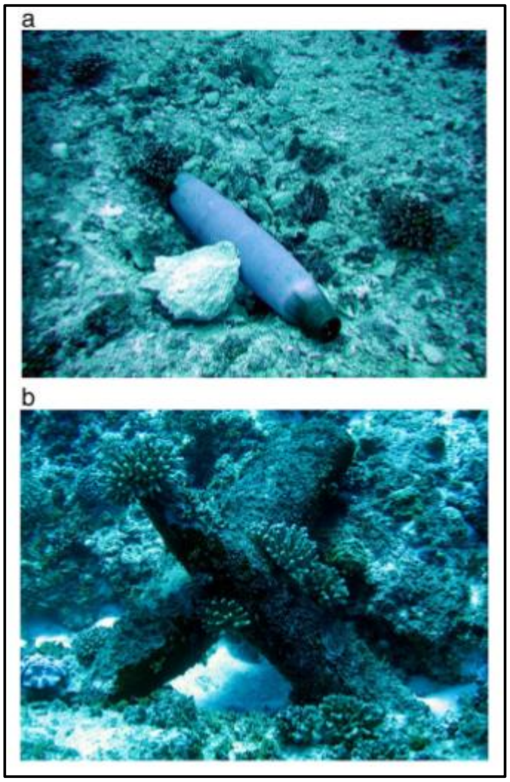


Figure 3.5-15: A 76-millimeter Cartridge Casing on Soft Bottom and a Blackbelly Rosefish (*Helicolenus dactylopterus*) Using the Casing for Protection When Disturbed

Note: The casing was observed in a sandy area on the continental slope approximately 425 meters in depth and 70 nautical miles east of Jacksonville, Florida. The casing has not become covered by sediments or encrusting organisms due to the depth and the relatively calm, current-free environment.

The impact of dense expendable materials on bottom substrate is prolonged in the portions of the study area that are seaward of the continental shelf. Between initial settlement and burial or complete degradation, these relatively stable objects will likely function as small artificial habitats for encrusting algae, attached macroalgae/seaweed, sedentary invertebrates as well as small motile organisms (Figure 3.5-16).

Disturbance of the bottom from ship hulks may occur, but impairment of habitat function is not expected because the material is sunk in the abyssal zone where bottom organisms are generally small and sparsely populated (Nybakken, 1993); the deep ocean has a sparse supply of food items for sedentary deposit or filter feeders. The only densely populated areas in the deep ocean are around the occasional hydrothermal vent/cold seep.



a. MK 82 inert bomb (168 centimeters long) that directly impacted the sea floor at a depth of 12 meters in Z3E on 5 or 6 September 2007; photographed on 13 September 2007. Area of destruction/ disturbance was approximately 17 square meters.

b. MK 82 bombs with Pocilloporid corals, algae, etc.

Source: (Smith & Marx, 2016)

Figure 3.5-16: Military Expended Materials Functioning as Habitat

To determine the potential level of disturbance that military expended materials have on soft, intermediate, and hard bottom substrates, an analysis to determine the impact footprint was conducted for each range complex for each alternative. Three main assumptions were made that result in the impact footprints calculated being considered overestimates. First, within each category of expended items (e.g., bombs, missiles, rockets, large-caliber projectiles, etc.), the size of the largest item that would be expended was used to represent the sizes of all items in the category. For example, the impact footprints of missiles used during training exercises range from 1.5 to 40 square feet. For the analyses, all missiles were assumed to be equivalent to the largest in size, or 40 square feet. Second, it was also assumed that the impact of the expended material on the seafloor was twice the size of its actual footprint. This assumption accounts for any displacement of sediments at the time of impact as well as any subsequent movement of the item on the seafloor due to currents or other forces. This should more accurately reflect the potential disturbance to soft bottom habitats, but would overestimate disturbance to hard bottom habitats since no displacement of the substrate would occur. Third, items with casings (e.g., small-, medium-, and large-caliber munitions; flares; sonobuoys; etc.) have their impact footprints doubled to account for both the item and its casing. Items and their casings were assumed to be the same size, even though, depending on the munitions, one of them is often smaller than the other.

Once the impact footprints were calculated, three analyses were performed for each range complex: (1) a conservative scenario in which potential impact to each habitat type (soft, intermediate, and hard bottom habitats) in that range complex if all expended materials settled in areas with that substrate type, (2) a proportional analysis in which potential impact to the each habitat type expended materials settled proportionally across all habitat types in the area, (3) and a 5-year scenario in which potential impact to the bottom habitats in that range complex over a 5-year period if activities continued at anticipated levels and impact accumulated over that period. During the analyses, the same dimensions were used for high-explosive munitions as were used for non-explosive practice munitions. The total area of the seafloor covered by the expended materials should be similar regardless of whether the item is intact or fragmented, despite the fact that high-explosive munitions will explode in the air, at the surface, or in the water column and only fragments would make it to the substrate.

According to surveys conducted at Farallon De Medinilla (a U.S. Department of Defense bombing range in the Mariana Archipelago) between 1997 and 2012, there was no evidence that the condition of the living resources assessed had changed or been adversely impacted to a significant degree by the training activities being conducted there. It should also be noted that the intended munition target was on the nearby land area, and water impacts were due to inaccuracy. The health, abundance, and biomass of fishes, corals, and other marine resources are comparable to or superior to those in similar habitats at other locations within the Mariana Archipelago (Smith & Marx, 2016). However, the study noted that decline in some important reef fish during their latest surveys was likely due to increasing attention from fishermen. Also, this is expected to be an extreme case based on the proximity to shallow-water coral reefs and the increased movement of military expended materials due to the shallow margins of the islands where wave impact is more severe. Impacts to habitat from military expended materials in the Study Area would be expected to be less severe. See Appendix F (Military Expended Material and Direct Strike Impact Analyses) for detailed analyses of the impacts associated with military expended materials from Navy training and testing activities.

3.5.3.4.3.1 Impacts from Military Expended Materials Under Alternative 1

Impacts from Military Expended Materials Under Alternative 1 for Training Activities

Training activities involving military expended materials (Appendix A, Navy Activity Descriptions) would have the potential to impact the marine substrates within the areas in which the training is occurring. Each range complex was evaluated to determine what level of impact could be expected under Alternative 1.

To determine the percentage of a given substrate within a range complex that may potentially be impacted by military expended materials under a conservative scenario for each of the alternatives, the total impacted area for each range complex was divided by the total amount of that particular substrate type within the same range complex as provided in Table 3.5-2 (see also Appendix F, Military Expended Material and Direct Strike Impact Analyses).

Military expended materials associated with training exercises under a conservative scenario would not impact more than 0.01 percent of the available soft bottom habitat annually within any of the training areas or range complexes. Likewise, the potential impact of the conservative scenario on intermediate bottom habitats within each range complex does not exceed 0.01 percent of the total available intermediate bottom. Impacts to hard substrate would not exceed 0.01 percent for any of the areas. Given that the probability of these conservative scenarios occurring is highly unlikely, the actual impact of military expended materials within each range complex under the Alternative 1 on hard bottom, intermediate bottom, or soft bottom substrates would be even less.

Decelerators/parachutes may be considered the worst potential impact on live hard bottoms in the Study Area due to the potential for such slowly sinking items to drift over shallow-water or deep-sea coral habitats. A decelerator/parachute settling on hard substrate would mean conversion to a softer material that could persist for a long time depending on the parachute material.

Additional analysis was conducted in order to determine the proportional impact of military expended materials from training activities on marine habitats in each of the training areas within the Study Area (Figure 3.5-17). Based on the proportional analysis of impacts, total proportional military expended materials impacts from training activities to vulnerable hard substrate would be approximately 6.5 acres. Impacts to other substrate types would be approximately 120.5 and 18.5 acres for intermediate and soft substrates, respectively. See Appendix F (Military Expended Material and Direct Strike Impact Analyses), for detailed analysis of military expended materials impacts from training activities in each range complex and other training locations.

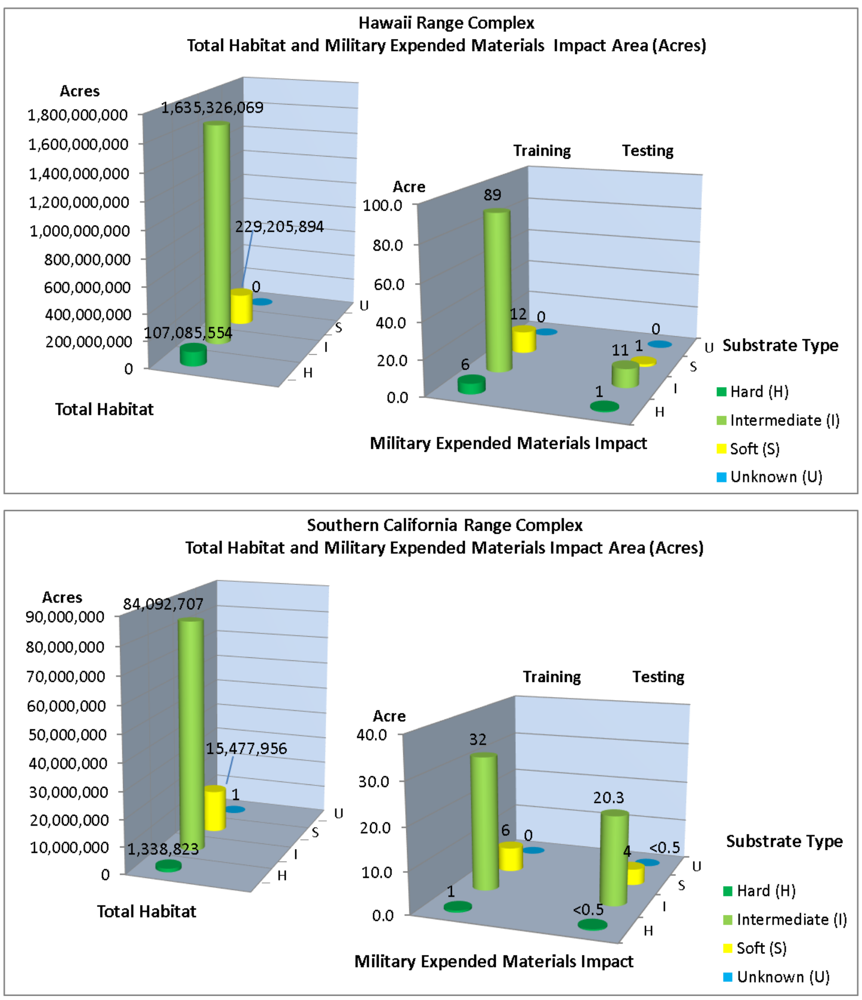


Figure 3.5-17: Alternative 1 – Proportional Impact (Acres) from Military Expended Materials by Substrate Type for Training and Testing Compared to Total Habitat Within the Study Area Over 1 Year

Analysis was also conducted to evaluate impacts accumulating over the course of a 5-year period. The analysis assumed that all impacts would accumulate. In reality, soft bottom habitats may recover in the short term where heavier military expended materials are buried under shifting sediments; hard bottom habitats would recover over the long term where hard, stable military expended materials become overgrown with similar organisms (Figure 3.5-16). The total proportional impact footprint for impacts from military expended materials over a 5-year period would be approximately 20.5, 412.5, and 64.0 acres for hard, intermediate, and soft bottom, respectively. However, total impacts would still affect less than 0.01 percent of the total area of each habitat type (hard, intermediate, and soft) would be impacted. Details of this analysis can be found in Appendix F (Military Expended Material and Direct Strike Impact Analyses).

Further, many of the military expended materials would be recovered, including torpedoes, unmanned aerial systems, targets, mine shapes, and instruments.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from military expended materials on habitats in mitigation areas throughout the Study Area. For example, the Navy will not conduct gunnery activities within a specified distance of shallow-water coral reefs and precious coral beds. Mitigation for seafloor resources was not included in the quantitative assessment of habitat impacts; however, it will help the Navy further avoid the potential for impacts on habitats from certain activities that involve the use of military expended materials.

Impacts from Military Expended Materials Under Alternative 1 for Testing Activities

Testing activities involving military expended materials (Appendix A, Navy Activity Descriptions) would have the potential to impact the marine substrates within the areas the testing is occurring. Each range complex and the HSTT Transit Lane was evaluated to determine what level of impact could be expected under Alternative 1.

To determine the percentage of the total soft bottom or hard bottom substrate within the Study Area that may potentially be impacted by military expended materials under a conservative scenario for each of the alternatives, the total impacted area for each range complex was divided by the total amount of that particular substrate type within the same range complex as provided in Table 3.5-2 (see also Appendix F, Military Expended Material and Direct Strike Impact Analyses).

Military expended materials associated with testing activities under a conservative scenario would not impact more than 0.01 percent of the available soft bottom habitat annually within any of the training areas or range complexes. Likewise, the potential impact of the conservative scenario on intermediate bottom habitats within each range complex does not exceed 0.01 percent of the total available intermediate bottom. Impacts to hard substrate would not exceed 0.01 percent for any of the areas. Given that the probability of these conservative scenarios occurring is highly unlikely, the actual impact of military expended materials within each range complex under Alternative 1 on hard bottom, intermediate bottom, or soft bottom substrates would be even less.

Additional analysis was conducted in order to determine the proportional impact of military expended materials from testing activities on marine habitats in each of the range complexes within the Study Area (Figure 3.5-17). Based on the proportional analysis of impacts, total military expended materials impacts to hard substrate from testing activities would be approximately 1.0 acre. Impacts to other substrate types would be approximately 31.5 and less than 5.5 acres for intermediate and soft substrates, respectively. Less than 0.5 acre of unknown substrate would be impacted. See Appendix F

(Military Expended Material and Direct Strike Impact Analyses) for detailed analysis of military expended materials impacts from testing activities in each range complex or other testing area.

Analysis was also conducted to evaluate impacts accumulating over the course of a 5-year period. The analysis assumed that all impacts would accumulate. In reality some habitat would recover over time, as soft substrates are dynamic systems and craters could refill. The total proportional impact footprint for impacts from high explosives over a 5-year period would be approximately 6.0, 204.5, and 35.0 acres for hard bottom, intermediate bottom, and soft bottom respectively. Less than 0.5 acre of unknown habitat would be impacted. However, total impacts would still affect less than 0.1 percent of the total area of each habitat type (hard, intermediate, and soft) would be impacted. Details of this analysis can be found in Appendix F (Military Expended Material and Direct Strike Impact Analyses).

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from military expended materials on habitats in mitigation areas throughout the Study Area. For example, the Navy will not conduct gunnery activities within a specified distance of shallow-water coral reefs, and precious coral beds. Mitigation for seafloor resources was not included in the quantitative assessment of habitat impacts; however, it will help the Navy further avoid the potential for impacts on habitats from certain activities that involve the use of military expended materials.

3.5.3.4.3.2 Impacts from Military Expended Materials Under Alternative 2

Impacts from Military Expended Materials Under Alternative 2 for Training Activities

Training activities involving military expended materials (Appendix A, Navy Activity Descriptions) would have the potential to impact the marine substrates within the areas the testing is occurring. Each range complex was evaluated to determine what the level of impact could be expected under Alternative 2.

As indicated in Section 3.0.3.3.4.2 (Military Expended Materials), under Alternative 2 the total number of military expended materials would be slightly greater in both the Hawaii Range Complex and the Southern California Range Complex than those analyzed under Alternative 1. Activities under Alternative 2 would occur in the same geographic locations using the same types of military expended materials as Alternative 1.

To determine the percentage of the total soft bottom, intermediate bottom, or hard bottom substrate within a training range that may potentially be impacted by military expended materials under a conservative scenario for each of the alternatives, the total impacted area for each training range was divided by the total amount of that particular substrate type within the same testing range. Results of this analysis are provided in Appendix F (Military Expended Material and Direct Strike Impact Analyses).

Military expended materials related to training activities under a conservative scenario would not impact more than 0.01 percent of the available soft bottom habitat annually within any of the training ranges. Likewise, the potential impact of the conservative scenario on intermediate bottom habitats within each training range does not exceed 0.01 percent of the total available intermediate bottom. Likewise, the potential impact of the conservative scenario on habitats within each training area, range complex, or other area does not exceed 0.01 percent of the total available hard bottom.

Analysis was conducted to evaluate impacts accumulating over the course of a 5-year period. The analysis assumed that all impacts would accumulate. In reality, soft bottom habitats may recover in the short term where heavier military expended materials are buried under shifting sediments; hard bottom habitats would recover over the long term where hard, stable military expended materials become overgrown with similar organisms. The total proportional impact footprint for impacts from high explosives over a 5-year period would be approximately 35.0, 665.0, and 107.5 acres for hard bottom, intermediate bottom, and soft bottom, respectively. Less than 0.5 acre of unknown habitat would be impacted. However, total impacts would still affect less than 0.01 percent of the total area of each habitat type (hard, intermediate, and soft). Details of this analysis can be found in Appendix F (Military Expended Material and Direct Strike Impact Analyses).

Given that the probability of these conservative scenarios occurring is highly unlikely, the actual impact of military expended materials within each range complex under Alternative 2 on either hard or soft bottom substrates would be even less than shown in Figure 3.5-17. Further, many of the military expended materials would be recovered, including, torpedoes, unmanned aerial systems, targets, mine shapes, and instruments.

Impacts from Military Expended Materials Under Alternative 2 for Testing Activities

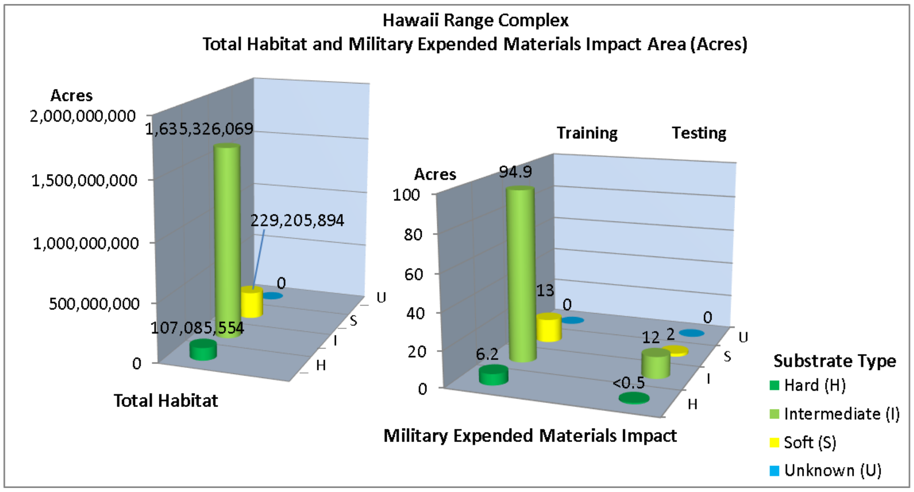
Testing activities involving military expended materials (Section 3.0.3.3.4, Physical Disturbance and Strike Stressors, and Appendix A, Navy Activity Descriptions) would have the potential to impact the marine substrates within the areas the testing is occurring. Each range complex was evaluated to determine what the level of impact could be expected under Alternative 2 (Figure 3.5-18).

Under Alternative 2 the total number of military expended materials would be the slightly greater in both the Hawaii Range Complex and the Southern California Range Complex than those analyzed under Alternative 1. Activities under Alternative 2 would occur in the same geographic locations using the same types of military expended materials as Alternative 1.

To determine the percentage of the total soft bottom, intermediate bottom, or hard bottom substrate within a testing range that may potentially be impacted by military expended materials under a conservative scenario for each of the alternatives, the total impacted area for each testing range was divided by the total amount of that particular substrate type within the same testing range. Results of this analysis are provided in Appendix F (Military Expended Material and Direct Strike Impact Analyses).

Military expended materials related to testing activities under a conservative scenario would not impact more than 0.1 percent of the available soft bottom habitat annually within any of the range complexes. Likewise, the potential impact of the conservative scenario on intermediate bottom habitats within each testing range does not exceed 0.1 percent of the total available intermediate bottom. The potential impact of the conservative scenario on habitats within each testing range does not exceed 0.1 percent of the total available hard bottom.

Analysis was conducted to evaluate impacts accumulating over the course of a 5-year period. The analysis assumed that all impacts would accumulate. In reality, over time, some habitat would recover as soft substrates are dynamic systems and craters could refill. The total proportional impact footprint for impacts from high explosives over a 5-year period would be approximately 7.0, 207.0, and 40.0 acres for hard bottom, intermediate bottom, and soft bottom, respectively. Less than 0.5 acre of unknown habitat would be impacted. However, total impacts would still affect less than 0.1 percent of the total area of each habitat type (hard, intermediate, and soft). Details of this analysis can be found in Appendix F (Military Expended Material and Direct Strike Impact Analyses).



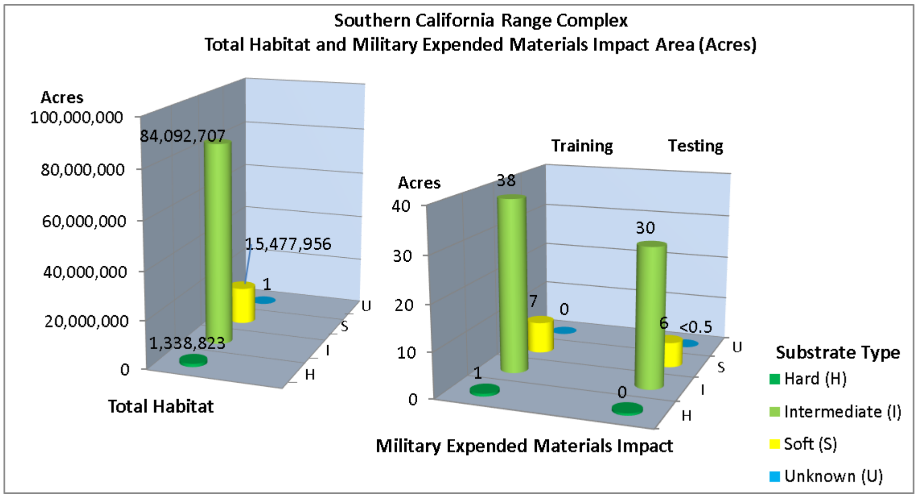


Figure 3.5-18: Alternative 2 – Proportional Impact (Acres) from Military Expended Materials by Substrate Type for Training and Testing Compared to Total Vulnerable Habitat Within the Study Area

Given that the probability of these conservative scenarios occurring is highly unlikely, the actual impact of military expended materials within each range complex under Alternative 2 on either hard or soft bottom substrates would be even less than shown in Figure 3.5-17.

Further, many of the military expended materials would be recovered, including, torpedoes, unmanned aerial systems, targets, mine shapes, and instruments.

3.5.3.4.3.3 Impacts from Military Expended Materials Under the No Action Alternative

<u>Impacts from Military Expended Materials Under the No Action Alternative for Training and Testing Activities</u>

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various physical disturbance and strike stressors (e.g., military expended materials) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.5.3.4.4 Impacts from Seafloor Devices

The types of activities that use seafloor devices are discussed in Appendix B (Activity Stressor Matrices), and Section 3.0.3.3.4.3 (Seafloor Devices) discusses where the devices are used and how many activities would occur under each alternative. Seafloor devices include items that are placed on, dropped on, or moved along the substrate for a specific purpose, and include mine shapes, anchor blocks, vessel anchors, bottom-placed instruments, bottom-crawling unmanned underwater vehicles, and bottom placed targets that are typically recovered (not expended). Mine shapes are typically deployed via surface vessels or fixed-wing aircraft. These items can damage fragile abiotic or biogenic structures on the bottom, temporarily cover and effectively replace an area of bottom, and resuspend sediment when deployed/retrieved.

3.5.3.4.4.1 Impacts from Seafloor Devices Under Alternative 1

Impacts from Seafloor Devices Under Alternative 1 for Training Activities

As indicated in Section 3.0.3.3.4.3 (Seafloor Devices), under Alternative 1, seafloor devices are deployed in the Hawaii Range Complex, Southern California Range Complex, and Silver Strand Training Complex as well as the San Diego Bay and Pearl Harbor. Activities involving seafloor devices have the potential to impact bottom habitats.

Mine shapes or other stationary targets and anchors are typically recovered within 7 to 30 days following the completion of the training or testing events. As a result of their temporary nature, recovered mine shapes do not permanently impact the substrate on which they are placed, but will temporarily impair the ability of the substrate to function as a habitat for as long as the mine shape and anchor is in place. The impairment is due to the temporary covering by artificial substrate along with changes in the bathymetry around the structures due to scouring and deposition patterns around objects on a soft bottom. Mine shapes, targets, or anchors that are not recovered would potentially have impacts to habitat similar to those discussed for military expended materials in Section 3.5.3.4.3 (Impacts from Military Expended Materials) and, depending on the type of bottom substrate, could alter the ability to function as habitat but ultimately would likely become buried (on soft bottom) or become encrusted by similar types of organisms (on hard, intermediate, or artificial surfaces).

Potential impacts of precision anchoring are qualitatively different from other seafloor devices because the activity involves repeated disturbance to the same area of seafloor. Precision anchoring training exercises involve releasing of anchors in designated locations. The intent of these training exercises is to practice anchoring the vessel within 300 ft. of the planned anchorage location. These training activities typically occur within predetermined shallow water anchorage locations near ports with seafloors consisting of soft bottom substrate. The level of impact to the soft sediments would depend on the size of the anchor used, which would vary according to vessel type. As most of these activities occur in areas along navigation channels subject to strong currents and shifting sediment, disturbed areas would quickly return to pre-disturbance conditions The Navy will implement mitigation that includes not conducting precision anchoring (except in designated anchorages) within the anchor swing circle of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks to avoid potential impacts from seafloor devices on habitats in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). Mitigation for seafloor resources was not included in the quantitative assessment of habitat impacts; however, it will help the Navy further avoid the potential for impacts on habitats from precision anchoring activities.

Crawlers are fully autonomous, battery-powered amphibious vehicles used for functions such as reconnaissance missions in territorial waters. These devices are used to classify and map underwater mines in shallow water areas. The crawler is capable of traveling 2 ft. per second along the seafloor and can avoid obstacles. The crawlers are equipped with various sonar sensors and communication equipment that enable these devices to locate and classify underwater objects and mines while rejecting miscellaneous clutter that would not pose a threat.

Crawlers move over the surface of the seafloor and would not harm or alter any hard substrates encountered; therefore, hard bottom habitat would not be impaired. However, fragile abiotic or biogenic structures could be harmed by the crawlers moving over the substrate (refer to living resources sections for analysis). In soft substrates, crawlers may leave a trackline of depressed sediments approximately 2 ft. wide (the width of the device) in their wake. However, since these crawlers operate in shallow water, any disturbed sediments would be redistributed by wave and tidal action shortly (days to weeks) following the disturbance. Therefore, disturbance would not impair the ability of soft sediment to function as a habitat.

The impact of seafloor devices on marine habitats from Alternative 1 training activities is likely to be inconsequential because: (1) the area exposed to the stressor is extremely small relative to overall availability of habitat of each type, (2) the activities are dispersed such that with the exception of precision mooring activities, few habitats would be exposed to multiple events, (3) impacts would be localized and those involving soft bottom would likely be temporary due to the dynamic nature of the habitats, and (4) sensitive habitats would tend to be avoided due to snagging or entanglement that could hinder recovery of the device. Activities involving seafloor devices are not expected to yield any discernable impacts on the overall availability or quality of habitat.

Impacts from Seafloor Devices Under Alternative 1 for Testing Activities

As indicated in Section 3.0.3.3.4.3 (Seafloor Devices), under Alternative 1, the use of seafloor devices occurs in the Southern California Range Complex in San Diego Bay.

Testing activities involving the use of anchor blocks, which are used to moor minefield targets and shapes and are deployed and recovered within the Hawaii Range Complex and Southern California Range Complex have the potential to impact bottom habitat. At the conclusion of the testing event, the minefield targets and shapes are typically recovered, but may be left in place.

Testing activities involving the use of bottom crawling unmanned underwater vehicles would occur within both the Hawaii Range Complex and Southern California Range Complex. Deployment of the bottom crawling unmanned underwater vehicles would mainly occur in waters less than 10 ft. in depth.

Impacts to habitats from Alternative 1 testing activities would be likely to be similar to those discussed above for training exercises. The impact of seafloor devices on marine habitats is likely to be inconsequential because: (1) the area exposed to the stressor is extremely small relative to overall availability of habitat of each type, (2) the activities are dispersed such that with the exception of precision anchoring activities, few habitats would be exposed to multiple events, (3) impacts would be localized and those involving soft bottom would likely be temporary due to the dynamic nature of the habitats, and (4) sensitive habitats would tend to be avoided due to snagging or entanglement that could hinder recovery of the device. Activities involving seafloor devices are not expected to yield any discernable impacts on the overall availability or quality of habitat.

The Navy will implement mitigation that includes not conducting precision anchoring (except in designated anchorages) within the anchor swing circle of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks to avoid potential impacts from seafloor devices on habitats in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). Mitigation for seafloor resources was not included in the quantitative assessment of habitat impacts; however, it will help the Navy further avoid the potential for impacts on habitats from precision anchoring activities.

3.5.3.4.4.2 Impacts from Seafloor Devices Under Alternative 2

Impacts from Seafloor Devices Under Alternative 2 for Training Activities

As indicated in Section 3.0.3.3.4.3 (Seafloor Devices), under Alternative 2, seafloor devices occur in the Hawaii Range Complex, Southern California Range Complex, and Silver Strand Training Complex as well as the San Diego Bay and Pearl Harbor.

Impacts to habitats from training activities under Alternative 2 would be likely to be the same as those discussed above for Alternative 1 training exercises. The impact of seafloor devices on marine habitats is likely to be inconsequential because: (1) the area exposed to the stressor is extremely small relative to overall availability of habitat of each type, (2) the activities are dispersed such that with the exception of precision mooring activities, few habitats would be exposed to multiple events, (3) impacts would be localized and those involving soft bottom would likely be temporary due to the dynamic nature of the habitats, and (4) sensitive habitats would tend to be avoided due to snagging or entanglement that could hinder recovery of the device. Activities involving seafloor devices are not expected to yield any discernable impacts on the overall availability or quality of habitat.

The Navy will implement mitigation to avoid potential impacts from seafloor devices on habitats, as discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources). For example, the Navy will use real-time geographic information system and Global Positioning System (along with remote sensing verification) data during deployment, installation, and recovery of anchors and mine-like objects to avoid impacts on shallow-water coral reefs and live hard bottom.

Impacts from Seafloor Devices Under Alternative 2 for Testing Activities

Under Alternative 2, the use of seafloor devices occurs in the Southern California Range in San Diego Bay. Testing activities involving the use of anchor blocks, used to moor minefield targets and shapes, which are deployed and recovered within the Hawaii Range Complex and Southern California Range Complex have the potential to impact bottom habitat.

Impacts to habitats from testing activities under Alternative 2 would be likely to be similar to those discussed above for Alternative 1 testing exercises, though use of seafloor devices in the Southern California Range Complex is slightly increased over Alternative 1. The impact of seafloor devices on marine habitats is likely to be inconsequential because: (1) the area exposed to the stressor is extremely small relative to overall availability of habitat of each type, (2) the activities are dispersed such that with the exception of precision mooring activities, few habitats would be exposed to multiple events, (3) impacts would be localized and those involving soft bottom would likely be temporary due to the dynamic nature of the habitats, and (4) sensitive habitats would tend to be avoided due to snagging or entanglement that could hinder recovery of the device. Activities involving seafloor devices are not expected to yield any discernable impacts on the overall availability or quality of habitat.

The Navy will implement mitigation to avoid potential impacts from seafloor devices on habitats, as discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources). For example, the Navy will use real-time geographic information system and Global Positioning System (along with remote sensing verification) data during deployment, installation, and recovery of anchors and mine-like objects to avoid impacts on shallow-water coral reefs and live hard bottom.

3.5.3.4.4.3 Impacts from Seafloor Devices Under the No Action Alternative

Impacts from Seafloor Devices Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various physical disturbance and strike stressors (e.g., seafloor devices) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.5.3.4.5 Impacts from Pile Driving

Pile driving and removal would involve driving of piles into soft substrate with an impact hammer. Pile driving may have the potential to impact soft bottom habitats temporarily during driving, removal, and in the short term thereafter.

3.5.3.4.5.1 Impacts from Pile Driving Under Alternative 1

Impacts from Pile Driving Under Alternative 1 for Training Activities

Under Alternative 1, Elevated Causeway System training would include pile driving and removal which could occur once per year in the nearshore and surf zone at one of the following locations: Silver Strand Training Complex designated Bravo Beach training lane or Camp Pendleton Amphibious Assault Area. While pile driving and removal may have the potential to impact soft bottom habitat, the impacts would be extremely limited since the number of piles is relatively small, and the duration is short (20 days for assembly and 10 days for disassembly). Piles would remain in the water for up to 60 days. Since pile driving would occur in the nearshore and surf zone areas, the dynamic nature of the soft bottom habitat is likely to return to its previous state shortly following removal of the temporary piles. However, the dispersed larvae forming new hard bottom communities may attach to the temporary structures instead of more permanent structures (see Section 3.4, Invertebrates, for details).

Impacts from Pile Driving Under Alternative 1 for Testing Activities

Pile driving stressors are not to habitats since pile driving would not occur under testing activities for Alternative 1 and are not analyzed further in this section.

3.5.3.4.5.2 Impacts from Pile Driving Under Alternative 2

Impacts from Pile Driving Under Alternative 2 for Training Activities

Under Alternative 2, elevated causeway system training would include pile driving and removal which could occur once per year in the nearshore and surf zone at one of the following locations: Silver Strand Training Complex designated Bravo Beach training lane or Camp Pendleton Amphibious Assault Area. While pile driving and removal may have the potential to impact soft-bottom habitat, the impacts would be extremely limited since the number of piles is relatively small, the duration is short (20 days for assembly and 10 days for disassembly). Piles would remain in the water for up to 60 days. Since pile driving would occur in the nearshore and surf zone areas, the dynamic nature of the soft bottom habitat is likely to return to its previous state shortly following removal of the temporary piles.

Impacts from Pile Driving Under Alternative 2 for Testing Activities

Pile driving stressors are not applicable to habitats since pile driving would not occur under testing activities for Alternative 2 and are not analyzed further in this section.

3.5.3.4.5.3 Impacts from Pile Driving Under the No Action Alternative

Impacts from Pile Driving Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various physical disturbance and strike stressors (e.g., pile driving) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.5.3.5 Entanglement Stressors

Entanglement stressors are not applicable to habitats due to the lack of mobility capabilities of habitats and are not analyzed further in this section.

3.5.3.6 Ingestion Stressors

Ingestion stressors are not applicable to habitats due to the lack of ingestion capabilities of habitats and are not analyzed further in this section.

3.5.3.7 Secondary Stressors

Secondary stressors are not applicable to habitats as they are not susceptible to impacts from secondary stressors and are not analyzed further in this section.

3.5.4 Summary of Potential Impacts on Habitats

3.5.4.1 Combined Impacts of All Stressors Under Alternative 1

Of all the potential stressors, only explosives on or near the bottom and military expended materials have any measureable potential to impact marine substrates as habitat for biological communities. The impact area for in-water explosions and military expended materials were all much less than 1 percent of the total area of documented soft bottom or hard bottom in their respective training or testing areas for each mapped substrate type, in both range complexes, over 1 year. Furthermore, impacts are expected to be negligible for unknown substrate type habitats. The impacts are unlikely to persist that long in most cases. Large and dense military expended materials (e.g., anchor blocks, large-caliber projectile casings, non-explosive bombs) deposited on the bottom along the outer continental shelf would be the most persistent. However, soft-bottom habitats may recover in the short term where heavier military expended materials are buried under shifting sediments; hard bottom habitats would recover over the long term where hard, stable military expended materials become overgrown with similar organisms.

The combined impact area of explosive stressors, physical disturbances, and strike stressors proposed for training and testing events in Alternative 1 would have minimal impact on the ability of soft bottom, intermediate bottom, or hard bottom to serve their function as habitat. Training activities under Alternative 1 would have a total footprint of potential impact across all habitat types of 145.0 acres from military expended materials and 16.0 acres from explosive detonations. This also represents less than 0.1 percent of the bottom habitat within the Study Area. Testing activities under Alternative 1 would have a total footprint of potential impact of 37.5 acres from military expended materials and 6.5 acres from explosive detonations across all habitat types. This also represents less than 0.1 percent of the bottom habitat within the Study Area. The combined total proportional impact for training and testing is primarily to soft bottom habitat, much less to hard and intermediate substrate habitats, and very little to areas with unknown substrate type (Figure 3.5-19). See Appendix F (Military Expended Material and Direct Strike Impact Analyses) for detailed impact analysis.

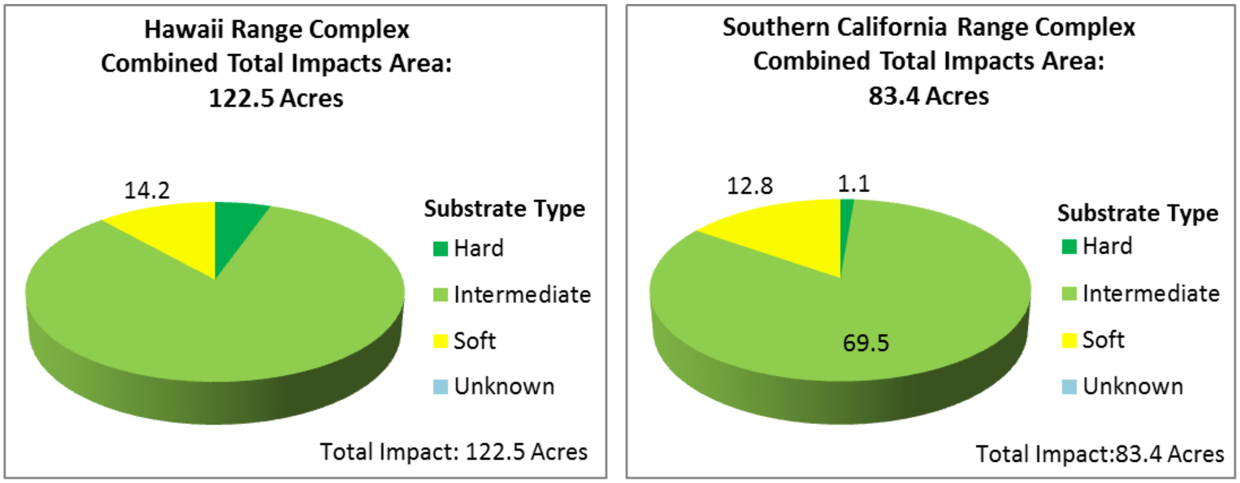


Figure 3.5-19: Combined Proportional Impact (Acres) from Explosives and Military Expended Materials by Substrate Type for Training and Testing Compared to Total Vulnerable Habitat Within the Study Area

3.5.4.2 Combined Impacts of All Stressors Under Alternative 2

The combined effects of explosive stressors, physical disturbances, and strike stressors proposed for training and testing events in Alternative 2 would have minimal impact on the ability of soft bottom, intermediate bottom, or hard bottom to function as habitat. Training activities under Alternative 2 would have a total footprint of potential impact of 160.5 acres across all habitat types from military expended materials and 16.0 acres from explosive detonations. This represents less than 0.01 percent of the bottom habitat within the Study Area. Testing activities under Alternative 2 would have a total footprint of potential impact of 51.0 acres from military expended materials and 8.0 acres from explosive detonations. This also represents less than 0.1 percent of the bottom habitat within the Study Area. See Appendix F (Military Expended Material and Direct Strike Impact Analyses) for detailed impact analysis.

3.5.4.3 Combined Impacts of All Stressors Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various explosives and physical disturbance and strike stressors (e.g., in-water detonations, military expended materials, seafloor devices, vessels and in-water device, and pile driving) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

REFERENCES

Ajemian, M. J., J. J. Wetz, B. Shipley-Lozano, J. D. Shively, and G. W. Stunz. (2015). An Analysis of Artificial Reef Fish Community Structure along the Northwestern Gulf of Mexico Shelf: Potential Impacts of "Rigs-to-Reefs" Programs. *PLoS ONE, 10*(5), e0126354.

Allee, R. J., M. Dethier, D. Brown, L. Deegan, R. G. Ford, T. F. Hourigan, J. Maragos, C. Schoch, K. Sealey, R. Twilley, M. P. Weinstein, and M. Yoklavich. (2000). *Marine and estuarine ecosystem and habitat classification* (NOAA Technical Memorandum NMFS-F/SPO-43).

Allen, L. G., and D. J. Pondella, II. (2006). Surf zone, coastal pelagic zone, and harbors. In L. G. Allen, D. J. Pondella, II, & M. H. Horn (Eds.), *The Ecology of Marine Fishes: California and Adjacent Waters*. Berkeley, CA: University of California Press.

Bacchiocchi, F., and L. Airoldi. (2003). Distribution and dynamics of epibiota on hard structures for coastal protection. *Estuarine, Coastal and Shelf Science, 56*, 1157–1166.

Berglind, R., D. Menning, R. Tryman, A. Helte, P. Leffler, and R. M. Karlsson. (2009). *Environmental Effects of Underwater Explosions: A Literature Study*. Kjeller, Norway: Forsvarets Forskningsinstitut.

Boehlert, G. W., and A. B. Gill. (2010). Environmental and ecological effects of ocean renewable energy development: A current synthesis. *Oceanography, 23*(2), 68–81.

Broughton, K. (2012). *Office of National Marine Sanctuaries Science Review of Artificial Reefs*. (Marine Sanctuaries Conservation Series ONMS-12-05). Silver Spring, MD: National Ocean Service, Office of National Marine Sanctuaries.

California Department of Fish and Game. (2001a). *A Guide to the Artificial Reefs of Southern California*. Retrieved from http://www.dfg.ca.gov/marine/artificialreefs/index.asp.

California Department of Fish and Game. (2001b). *Artificial Reef Coordinates in Southern California (Appendix 1)*. Retrieved from http://www.dfg.ca.gov/marine/artificialreefs/appendix1.pdf.

California Department of Fish and Game. (2009). *Regional Profile of the MLPA South Coast Study Region (Point Conception to the California-Mexico Border)*. Sacramento, CA: California Marine Life Protection Act Initiative, California Natural Resources Agency.

California State Lands Commission. (2017). *Oil and Gas Leases*. Retrieved from http://www.slc.ca.gov/Info/Oil_Gas.html.

Clark, M. R., F. Althaus, T. A. Schlacher, A. Williams, D. A. Bowden, and A. A. Rowden. (2016). The impacts of deep-sea fisheries on benthic communities: A review. *ICES Journal of Marine Science: Journal du Conseil, 73*(Supplement 1), i51–i69.

Clarke, M. C., M. E. Mach, and R. G. Martone. (2014). *Cumulative effects in marine ecosystems: Scientific perspectives on its challenges and solutions* (WWF-Canada and Center For Ocean Solutions). Vancouver, Canada: World Wide Fund for Nature and the Center for Ocean Solutions.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. (1979). *Classification of Wetlands and Deepwater Habitats of the United States*. Washington, DC: Northern Prairie Wildlife Research Center Home Page. Retrieved from http://www.npwrc.usgs.gov/resource/1998/classwet/classwet.htm.

Crain, C. M., B. S. Halpern, M. W. Beck, and C. V. Kappel. (2009). Understanding and Managing Human Threats to the Coastal Marine Environment. In R. S. Ostfeld & W. H. Schlesinger (Eds.), *The Year* *in Ecology and Conservation Biology, 2009* (pp. 39–62). Oxford, United Kingdom: Blackwell Publishing.

Davis, A. R. (2009). The role of mineral, living and artificial substrata in the development of subtidal assemblages. In M. Wahl (Ed.), *Marine Hardbottom Communities: Patterns, Dynamics, Diversity and Change* (Vol. 206, pp. 19–37). New York, NY: Springer-Verlag.

Dugan, J. E., D. M. Hubbard, M. D. McCrary, and M. O. Pierson. (2003). The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. *Estuarine, Coastal and Shelf Science, 58* (10), 25–40.

Friedlander, A., K. Keller, L. Wedding, A. Clark, and M. Monaco. (2009). *A Marine Biogeographic Assessment of the Northwestern Hawaiian Islands*. Silver Spring, MD: Office of National Marine Sanctuaries Papahanaumokuakea Marine National Monument.

Garcia, A., and J. R. Smith. (2014). Factors influencing human visitation of southern California rocky intertidal ecosystems. *Ocean & Coastal Management, 73*, 44–53.

Gorodilov, L. V., and A. P. Sukhotin. (1996). Experimental investigation of craters generated by explosions of underwater surface charges on sand. *Combustion, Explosion, and Shock Waves, 32*(3), 344–346.

Halpern, B., S. Walbridge, K. A. Selkoe, C. V. Kappel, F. Micheli, C. D'Agrosa, J. F. Bruno, K. S. Casey, C. Ebert, H. E. Fox, R. Fujita, D. Heinemann, H. S. Lenihan, E. M. P. Madin, M. T. Perry, E. R. Selig, M. Spalding, R. S. Steneck, and R. Watson. (2008). A global map of human impact on marine ecosystems. *Science, 319*(5865), 948–952.

Hanson, J., M. Helvey, and R. Strach. (2003). *Non-Fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures*. Silver Spring, MD: National Marine Fisheries Service, Alaska Region, Northwest Region, Southwest Region.

Hawaii Division of Aquatic Resources (Cartographer). (2006). *Hawaii's Five Artificial Reefs & Corresponding Commercial Fish Catch Areas—Map* [Electronic Map]. Retrieved from http://dlnr.hawaii.gov/dar/fishing/artificial-reefs-and-fads/.

Hoegh-Guldberg, O., and J. F. Bruno. (2010). The impact of climate change on the world's marine ecosystems. *Science, 328*(5985), 1523–1528.

Holland, K. T., and P. A. Elmore. (2008). A review of heterogeneous sediments in coastal environments. *Earth-Science Reviews, 89*(3–4), 116–134.

Howell, E. A., P. H. Dutton, J. J. Polovina, H. Bailey, D. M. Parker, and G. H. Balazs. (2010). Oceanographic influences on the dive behavior of juvenile loggerhead turtles (*Caretta caretta*) in the north Pacific Ocean. *Marine Biology, 157*(5), 1011–1026.

Karleskint, G., Jr. , R. Turner, and J. W. Small, Jr. (2006). *Introduction to Marine Biology* (2nd ed.). Belmont, CA: Thomson Brooks/Cole.

Keener, V. W., J. J. Marra, M. L. Finucane, D. Spooner, and M. H. Smith. (2012). *Climate Change and Pacific Islands: Indicators and Impacts. Report for the 2012 Pacific Islands Regional Climate Assessment*. Washington, DC: Island Press.

Kendall, M. S., M. E. Monaco, K. R. Buja, J. D. Christensen, C. R. Kruer, M. Finkbeiner, and R. A. Warner. (2001). *Methods Used to Map the Benthic Habitats of Puerto Rico and the U.S. Virgin Islands*. Silver Spring, MD: National Oceanic and Atmospheric Administration, National Ocean Service, National Centers for Coastal Ocean Science Biogeography Program.

Lalli, C. M., and T. R. Parsons. (1993). *Biological Oceanography: An Introduction*. New York, NY: Pergamon Press.

Leggett, C., N. Scherer, M. Curry, R. Bailey, and T. Haab. (2014). *Assessing the Economic Benefits of Reductions in Marine Debris: A Pilot Study of Beach Recreation in Orange County, California. Final Report.* Silver Springs, MD: National Oceanic and Atmospheric Administration, Marine Debris Division.

Lotze, H. K., H. S. Lenihan, B. J. Bourque, R. H. Bradbury, R. G. Cooke, M. C. Kay, S. M. Kidwell, M. X. Kirby, C. H. Peterson, and J. B. Jackson. (2006). Depletion, degradation, and recovery potential of estuaries and coastal seas. *Science, 312*(5781), 1806–1809.

Macreadie, P. I., A. M. Fowler, and D. J. Booth. (2011). Rigs-to-reefs: Will the deep sea benefit from artificial habitat? *Frontiers in Ecology and the Environment, 9*(8), 455–461.

Maragos, J. E. (2000). Hawaiian Islands (U.S.A.). In C. R. C. Sheppard (Ed.), *Seas at the Millennium: An Environmental Evaluation* (Vol. 2: Regional chapters: The Indian Ocean to the Pacific, pp. 791–812). Amsterdam, Netherlands: Pergamon Press.

Menge, B. A., and G. M. Branch. (2001). Rocky intertidal communities. In M. D. Bertness, S. D. Gaines, & M. E. Hay (Eds.), *Marine Community Ecology* (pp. 221–252). Sunderland, MA: Sinauer Associates, Inc.

Messner, S., L. Moran, G. Reub, and J. Campbell. (2013). Climate change and sea level rise impacts at ports and a consistent methodology to evaluate vulnerability and risk. *WIT Transactions on Ecology and the Environment*.

Miller, J. (1994). Review of the physical oceanographic conditions within the designated sanctuary. In K. Des Rochers (Ed.), *A Site Characterization Study for the Hawaiian Islands Humpback Whale National Marine Sanctuary* (pp. 9–18). Honolulu, HI: University of Hawaii Sea Grant Program.

Murray, S. N., T. G. Denis, J. S. Kido, and J. R. Smith. (1999). *Human Visitation and the Frequency and Potential Effects of Collecting on Rocky Intertidal Populations in Southern California Marine Reserves* (California Cooperative Oceanic Fisheries Investigations Report). Fullerton, CA: California State University, Fullerton.

National Oceanic and Atmospheric Administration. (2007). *National Artificial Reef Plan (as Amended): Guidelines for siting, construction, development, and assessment of artifical reefs*. Washington, DC: U.S. Department of Commerce.

National Oceanic and Atmospheric Administration. (2017). *Maritime Heritage in Papahanaumokuakea Marine National Monument*. Retrieved from https://www.papahanaumokuakea.gov/maritime/.

National Oceanic and Atmospheric Administration Marine Debris Program. (2016). *Marine Debris Impacts on Coastal and Benthic Habitats*. Silver Spring, MD: National Oceanic and Atmospheric Administration.

Newell, R. C., L. J. Seiderer, and D. R. Hitchcock. (1998). The Impact of Dredging Works in Coastal Waters: A Review of the Sensitivity to Disturbance and Subsequent Recovery of Biological Resources on the Sea Bed. *Oceanography and Marine Biology: An Annual Review, 36*, 127–178.

Nybakken, J. W. (1993). *Marine Biology, an Ecological Approach* (3rd ed.). New York, NY: Harper Collins College Publishers.

O'Keeffe, D. J., and G. A. Young. (1984). *Handbook on the Environmental Effects of Underwater Explosions*. Silver Spring, MD: U.S. Navy, Naval Surface Weapons Center (Code R14).

Perkol-Finkel, S., N. Shashar, and Y. Benayahu. (2006). Can artificial reefs mimic natural reef communities? The roles of structural features and age. *Marine Environmental Research, 61*, 121–135.

Powers, S. P., J. H. Grabowski, C. H. Peterson, and W. J. Lindberg. (2003). Estimating enhancement of fish production by offshore artificial reefs: uncertainty exhibited by divergent scenarios. *Marine Ecology Progress Series, 264*, 265–277.

Reed, D., S. Schroeter, and M. Page. (2010). *Annual Report of the Status of Condition C: Kelp Reef Mitigation* (San Onofre Nuclear Generating Station Mitigation Program). Submitted to the California Coastal Commission.

Ross, S. W., M. Rhode, S. T. Viada, and R. Mather. (2016). Fish species associated with shipwreck and natural hard-bottom habitats from the middle to outer continental shelf of the Middle Atlantic Bight near Norfolk Canyon. *Fishery Bulletin, 114*(1), 45–57.

Scavia, D., J. C. Field, D. F. Boesch, R. W. Buddemeier, V. Burkett, D. R. Cayan, M. Fogarty, M. A. Harwell, R. W. Howarth, C. Mason, D. J. Reed, T. C. Royer, A. H. Sallenger, and J. G. Titus. (2002). Climate Change Impacts on U.S. Coastal and Marine Ecosystems. *Estuaries, 25*(2), 149–164.

SEPM Strata. (2018). *Tide Dominated Deltas*. Retrieved from http://www.sepmstrata.org/page.aspx?pageid=313.

Smith, S. H., and D. E. Marx, Jr. (2016). De-facto marine protection from a Navy bombing range: Farallon de Medinilla, Mariana Archipelago, 1997 to 2012. *Marine Pollution Bulletin, 102*(1), 187–198.

Speybroeck, J., D. Bonte, W. Courtens, T. Gheskiere, P. Grootaert, J. P. Maelfait, S. Provoost, K. Sabbe, E. W. M. Stienen, V. Van Lancker, W. Van Landuyt, M. Vincx, and S. Degraer. (2008). The Belgian sandy beach ecosystem: A review. *Marine Ecology–an Evolutionary Perspective, 29*(Supplement 1), 171–185.

Stephens, M. P., D. C. Kadko, C. R. Smith, and M. Latasa. (1997). Chlorophyll-a and pheopigments as tracers of labile organic carbon at the central equatorial Pacific seafloor. *Geochimica et Cosmochimica Acta, 61*(21), 4605–4619.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, and National Marine Sanctuary Program. (2008). *Channel Islands National Marine Sanctuary final management plan/final environmental impact statement*. Silver Spring, MD.

U.S. Department of the Navy. (2010). *Jacksonville Range Complex Operating Area Undersea Warfare Training Range Bottom Mapping and Habitat Characterization, Florida. Final Cruise Report*. Jacksonville, FL: Naval Facilities Engineering Command Atlantic.

U.S. Department of the Navy. (2011). *CC Range Bottom Mapping and Habitat Characterization, Florida. Final Cruise Report*. Norfolk, VA: Naval Facilities Engineering Command Atlantic.

U.S. Department of the Navy. (2018). *Building and Maintaining a Comprehensive Database and Prioritization Scheme for Overlapping Habitat Data – Focus on Abiotic Substrates in the Atlantic Fleet Training and Testing Study Area*. (Phase III AFTT Benthic Habitat Database Technical Report). Washington, DC: Naval Facilities Engineering Command.

United Nations Educational Scientific and Cultural Organization. (2009). *Global Open Oceans and Deep Seabed—Biogeographic Classification*. Paris, France: UNESCO - IOC.

University of Hawaii. (2014). *Climate Change Impacts in Hawaii - A Summary of Climate Change and Its Impacts to Hawaii's Ecosystems and Communities* (UNIHI-SEAGRANT-TT-12-04). Honolulu, HI: University of Hawaii.

University of Hawaii. (2016). *State of Hawaii’s Fish Aggregation Device Program*. Retrieved from http://www.hawaii.edu/HIMB/FADS/.

Valentine, P. C., B. J. Todd, and V. E. Kostylev. (2005). Classification of Marine Sublittoral Habitats, with Application to the Northeastern North America Region. *American Fisheries Society Symposium, 41*, 183–200.

Whitmire, C. E., and M. E. Clarke. (2007). *State of Deep Coral Ecosystems of the U.S. Pacific Coast: California to Washington* (The State of Deep Coral Ecosystems of the United States). Silver Spring, MD: U.S. Department of Commerce and National Oceanic and Atmospheric Administration.

Wiener, C. S., M. D. Needham, and P. F. Wilkinson. (2009). Hawaii's real life marine park: interpretation and impacts of commercial marine tourism in the Hawaiian Islands. *Current Issues in Tourism, 12*(5-6), 489–504.

Zabawa, C., and C. Ostrom. (1980). *Final Report on the Role of Boat Wakes in Shore Erosion in Anne Arundel County, Maryland*. Annapolis, MD: Maryland Department of Natural Resources.

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3.6 FISHES

PREFERRED ALTERNATIVE SYNOPSIS

The United States Department of the Navy considered all potential stressors that fishes could be exposed to from the Proposed Action. The following conclusions have been reached for the Preferred Alternative (Alternative 1):

- Acoustics: The use of sonar and other transducers, air guns, pile driving, vessel noise, aircraft noise, and weapons noise could result in impacts on fishes in the Study Area. Some sonars and other transducers, vessel noise, and weapons noise could result in hearing loss, masking, physiological stress, or behavioral reactions. Aircraft noise would not likely result in impacts other than brief, mild behavioral responses in fishes that are close to the surface. Air guns and pile driving have the potential to result in the same effects in addition to mortality or injury. Most impacts, such as masking or behavioral reactions, are expected to be temporary and infrequent as most activities involving acoustic stressors would be at low levels of noise, temporary, localized, and infrequent. More severe impacts such as mortality or injury could lead to permanent or long-term consequences for individuals but, overall, long-term consequences for fish populations are not expected.
- Explosives: The use of explosives could result in impacts on fishes within the Study Area. Sound and energy from explosions is capable of causing mortality, injury, hearing loss, masking, physiological stress, or behavioral responses. The time scale of individual explosions is very limited, and training and testing exercises involving explosions are dispersed in space and time; therefore, repeated exposure of individual fishes are unlikely. Most effects such as hearing loss or behavioral responses are expected to be short-term and localized. More severe impacts such as mortality or injury could lead to permanent or long-term consequences for individuals but, overall, long-term consequences for fish populations are not expected.
- Energy: The use of in-water electromagnetic devices may elicit brief behavioral or physiological stress responses only in those exposed fishes with sensitivities to the electromagnetic spectrum. This behavioral impact is expected to be temporary and minor. Similar to regular vessel traffic that is continuously moving and covers only a small spatial area during use, in-water electromagnetic fields would be continuously moving and cover only a small spatial area during use; thus, population-level impacts are unlikely.
- Physical Disturbance and Strike: Impacts on fishes from vessel strikes, in-water device strikes, military expended material strikes, and seafloor device strikes are highly unlikely because most fishes are highly mobile and have sensory capabilities that enable the detection and avoidance of vessels, expended materials, or objects in the water column or on the seafloor. The only exceptions are a few large, slow-moving species such as manta rays, ocean sunfish, and whale sharks that occur near the surface in some areas. Long-term consequences from vessel strikes for individuals and for fish populations are not expected.
- Entanglement: Fishes could be exposed to multiple entanglement stressors associated with Navy training and testing activities. The potential for impacts is dependent on the physical properties of the expended materials and the likelihood that a fish would encounter a potential entanglement stressor and then become entangled in it. Physical characteristics of wires and cables, decelerators/parachutes, and biodegradable polymers, combined with the sparse distribution of these items throughout the Study Area, indicates a very low potential for fishes to encounter and become entangled in them. Because of the low numbers of fishes potentially impacted by entanglement stressors, population-level impacts are unlikely.

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- Ingestion: The likelihood that expended items would cause a potential impact on a given fish species depends on the size and feeding habits of the fish and the rate at which the fish encounters the item and the composition of the item. Military expended materials from munitions present an ingestion risk to fishes that forage in the water column and on the seafloor. Military expended materials other than munitions present an ingestion risk for fishes foraging at or near the surface while these materials are buoyant, and on the seafloor when the materials sink Because of the low numbers of fishes potentially impacted by ingestion stressors, population-level impacts are unlikely.
- Secondary: Effects on sediment or water quality would be minor, temporary, and localized and could have short-term, small-scale secondary effects on fishes; however, there would be no persistent or large-scale effects on the growth, survival, distribution, or populations of fishes.

3.6.1 INTRODUCTION

This section analyzes the potential impacts of the Proposed Action on fishes found in the Study Area. Section 3.6.2.2 (Endangered Species Act-Listed Species) introduces the Endangered Species Act (ESA) species that occur in the Study Area, and taxonomic groupings are discussed in Section 3.6.2.3 (Species Not Listed Under the Endangered Species Act). The complete analysis of environmental consequences is in Section 3.6.3 (Environmental Consequences) and the potential impacts of the Proposed Action on marine fish species are summarized in Section 3.6.4 (Summary of Potential Impacts on Fishes).

For this Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS), marine fish are evaluated as groups of species characterized by distribution, morphology (body type), or behavior relevant to the stressor being evaluated. Activities are evaluated for their potential effects on the marine fish in the Study Area that are listed, proposed, or candidate species under the ESA, as well as other fish in the Study Area. Fishes are not distributed uniformly throughout the Study Area but are closely associated with a variety of habitats. Some species, such as large sharks, salmon, tuna, and billfishes, range across thousands of square miles. Other species, such as gobies and most reef fish, generally have small home ranges and restricted distributions (Helfman et al., 2009). The early life stages (e.g., eggs and larvae) of many fish may be widely distributed even when the adults have relatively small ranges. The movements of some open-ocean species may never overlap with coastal fishes that spend their lives within several hundred feet of the shore. The distribution and specific habitats in which an individual of a single fish species occurs may be influenced by its life stage, size, sex, reproductive condition, and other factors. Approximately 78 percent of all marine fish species occur in waters less than 200 meters (m) deep and in close association with land, while 13 percent are associated with the open ocean (Moyle & Cech, 2004).

3.6.2 AFFECTED ENVIRONMENT

Three subsections are included in this section. General background information is given in Section 3.6.2.1 (General Background), which provides brief summaries of habitat use, movement and behavior, and threats that affect or have the potential to affect fishes within the Study Area. Protected species listed under ESA are described in Section 3.6.2.2 (Endangered Species Act-Listed Species). Fishes not listed under the ESA are briefly reviewed in Section 3.6.2.3 (Species Not Listed Under the Endangered Species Act).

3.6.2.1 General Background

Fishes are the most numerous and diverse of the major vertebrate groups (Moyle & Cech, 2004). It is estimated that there are currently over 34,000 species of fishes worldwide (Eschmeyer & Fong, 2017), with greater than half that number of species inhabiting the oceans.

Marine fishes can be broadly categorized by their distributions within the water column or habitat usage. Moyle and Cech (2004) define the major marine habitat categories as estuaries, coastal habitats, reefs, the epipelagic zone, the deep sea, and the Polar regions. In the Study Area, the major habitat categories include all of the aforementioned except the Polar regions. Many marine fishes that occur in the Study Area are either demersal species (i.e., close to the seafloor) associated with nearshore coastal reefs, or are more oceanic and live in surface waters (pelagic) further offshore (Schwartz, 1989). The highest number and diversity of fishes typically occur where the habitat has structural complexity (reef systems, continental slopes, deep canyons), biological productivity (areas of nutrient upwelling), and a variety of physical and chemical conditions (water flow, nutrients, dissolved oxygen, and temperature) (Bergstad et al., 2008; Helfman et al., 2009; Moyle & Cech, 2004; Parin, 1984). Some of the marine fishes that occur in the coastal zone migrate between marine and freshwater habitats (Helfman et al., 2009). Other distribution factors, including predator/prey relationships, water quality, and refuge (e.g., physical structure or vegetation cover) operate, on more regional or local spatial scales (Reshetiloff, 2004). Also, fishes may move among habitats throughout their lives based on changing needs during different life stages (Schwartz, 1989).

Each major habitat type in the Study Area (e.g., reef, hard bottom, soft bottom, and beds of submerged aquatic vegetation) supports an associated fish community with the number of species increasing with decreasing latitude (transition from north to south). However, this pattern is not as clearly defined for wide-ranging migratory open-ocean species (Macpherson, 2002). The specific characteristics of the wide diversity of habitat and biotic species that make up these habitat types within the Study Area are discussed in Section 3.3 (Vegetation), Section 3.4 (Invertebrates), and Section 3.5 (Habitats).

Some fish species in the United States are protected under the ESA and are managed by either the United States (U.S.) Fish and Wildlife Service (USFWS) or National Marine Fisheries Service (NMFS). The recreational and commercial fisheries are managed within a framework of overlapping international, federal, state, interstate, and tribal authorities. Individual states and territories generally have jurisdiction over managed fisheries located in marine waters within 3 nautical miles (NM) of their coast. Federal jurisdiction includes managed fisheries in marine waters inside the U.S. Exclusive Economic Zone. The area stretches from the outer boundary of state waters out to 200 NM offshore of any United States coastline, except where intersected closer than 200 NM by bordering countries.

The Magnuson-Stevens Fishery Conservation and Management Act and Sustainable Fisheries Act led to the formation of eight regional fishery management councils that coordinate with NMFS to manage and conserve certain fisheries in federal waters. Together with NMFS, the councils maintain fishery management plans for species or species groups comprised of fish, invertebrates, and vegetation to regulate commercial and recreational harvest within their geographic regions. The Study Area overlaps with the jurisdiction of two regional fishery management councils, as well as the range of the highly migratory species (e.g., sharks, billfishes, swordfish, and tunas), which are managed directly by NMFS.

- **The Western Pacific Regional Fishery Management Council** includes Hawaii, American Samoa, Guam, and the Northern Mariana Islands.
- **The Pacific Fishery Management Council** includes Washington, Oregon, and California.
- **NMFS, Office of Sustainable Fisheries** includes all federally managed waters of the United States where highly migratory species occur.

3.6.2.1.1 Habitat Use

Fishes inhabit most of the world's oceans, from warm shallow coastal habitat to cold deep-sea waters, and are found on the surface, in the water column, and at the bottom in the Study Area. The description of habitat use in this section pertains to common fishes found in the different habitats. The abiotic (non-living) components of all habitat types are addressed in Section 3.5 (Habitats), habitat-forming invertebrates (e.g., coral, sponges, etc.) are covered in Section 3.4 (Invertebrates), sediment and water quality conditions are addressed in Section 3.2 (Sediments and Water Quality) and marine vegetation components are discussed in Section 3.3 (Vegetation).

Fish distribution is restricted by biotic factors (competition or predation) or by abiotic components, such as temperature, salinity, dissolved oxygen, and pH. A species can be excluded from a suitable habitat by competitors, predators, parasites, or a lack of available prey (Moyle & Cech, 2004). For example, Catano et al. (2015) found that a loss of corals and the resulting decline in structural complexity, as well as management efforts to protect reefs, could alter the territory dynamics and reproductive potential of important herbivorous fish species.

Estuaries are comprised of brackish water, where freshwater mixes with saltwater to form transitional environments between rivers and the ocean. The fluctuating nature of the estuarine environment means that the fishes inhabiting or transiting through expend considerable amounts of energy adjusting to the changing conditions. Fishes found in estuaries are of five broad types: (1) freshwater (e.g., nonnative catfishes [*Ictalurus* species]), (2) diadromous species that spend part of their lives in freshwater and part of their lives in saltwater (e.g., sturgeon and salmon), (3) true estuarine (e.g., Delta smelt [*Hypomesus transpacificus*]), (4) marine species that use estuaries but do not necessarily need them (e.g., starry flounder (*Platichthyes stellatus*]), and (5) marine species that need estuaries for at least one stage of their lives (e.g., herrings [*Clupea* species]) (Moyle & Cech, 2004). Estuaries are primarily composed of soft bottom (e.g., sand and sandy sediments and mudflats), and many contain a variety of benthic habitat types such as seagrass beds and hard substrate such as oyster reefs.

Marine and diadromous fishes inhabit the diverse coastal habitats on or near the edges of the continents, from the intertidal regions to the edge of the continental shelf (Moyle & Cech, 2004). The most abundant and conspicuous types of coastal habitats are hard bottom (e.g., rocky reefs which can include shell beds), soft bottom (e.g., sand, mud, silt), submerged aquatic vegetation (e.g., mangroves, salt marshes, seagrass beds, macroalgae beds), and floating macroalgae. Each of these coastal habitats has distinct types of fishes associated with it. Common fishes inhabiting hard bottom habitats in the Study Area include gobies (Gobiidae), rockfishes (Scorpaenidae), and sculpins (Cottidae), while flounder (Bothidae) and stingrays (Dasyatidae) are found on soft bottoms. Pipefishes (Syngnathidae) and kelpfish (Clinidae) are common inhabitants of submerged aquatic vegetation habitat. Species commonly found under offshore floating macroalgae include ocean sunfishes, tunas, sharks, and mahi mahi.

Somewhere between 30 and 40 percent of all fish species are associated with hard bottom habitats (tropical and subtropical) such as reefs, and anywhere from 250 to 2,200 species are likely to be found in, on, or near a major complex of reefs. Coral reef habitats are found between latitudes 30° North (N) and 30° South (S) in shallow water (usually less than 164 feet [ft.]) that is warm enough to support the growth of corals and clear enough to allow photosynthesis at moderate depths. Most reef habitats are surrounded by nutrient-poor oceanic waters. Compared to the total number of species of carnivorous fishes that inhabit low-latitude coral reefs, the number of herbivores is small (20 percent), but they are often the most noticeable fishes (Moyle & Cech, 2004). Damselfishes (Pomacentridae), parrotfishes (Scaridae), and surgeonfishes (Acanthuridae) are examples of herbivorous fishes found in reef habitat (Moyle & Cech, 2004). In the Study Area, commonly recognized reef fishes include butterflyfishes (Chaetodontidae), puffers (Tetraodontidae), tangs (Acanthuridae), triggerfishes (Balistidae), and wrasses (Labridae).

The upper 200 m of the ocean is known as the photic or epipelagic zone. Sunlight penetrates sufficiently to support the growth of phytoplankton or macro algae. The area between 200 m and 1,000 m is referred to as the mesopelagic zone, where light penetration is minimal. Below the mesopelagic zone is the bathypelagic or aphotic zone, where sunlight does not penetrate. A lack of habitat complexity can limit the number of fish species that inhabit the epipelagic zone. Less than two percent of all fish species inhabit the nutrient-poor waters, with most occurring in the upper 100 m of the water column, where light can penetrate and permit phytoplankton growth and visual predators to see their prey. Epipelagic fishes are divided for convenience into nearshore and oceanic groups. Nearshore epipelagic fishes are overall the most commercially valuable group of fishes to humans because they typically occur in large schools, such as herring (Clupeidae) and anchovies (Engraulidae), or are particularly favored as food, such as tunas (Scombridae) and salmon (Salmonidae). Predators on nearshore epipelagic fishes include billfishes and swordfishes (Xiphiidae), sharks (Carcharhinidae), and others. Epipelagic fishes that inhabit the open ocean spend their entire life cycle either free swimming or associated with drifting seaweed e.g., kelp (Moyle & Cech, 2004). In the Study Area, examples of epipelagic open ocean fishes include sharks, tunas, sauries (Scomberesocidae), and ocean sunfish (Molidae).

Mesopelagic habitats are found below the well-lighted, well-mixed epipelagic zone. Between about 120 m and 1,000 m in depth, light gradually fades to extinction, and the water temperatures decreases to 39°Fahrenheit (F). Below 1,000 m, bathypelagic habitats are characterized by complete darkness, low temperatures, low nutrients, low dissolved oxygen, and great pressure. This environment is the most extensive aquatic habitat on earth. The vastness of the deep-sea habitat, coupled with its probable stability through geological time, has led to the development of a diverse fish community, which accounts for 11 percent of all recorded fish species in the oceans. Lanternfishes (Myctophidae), with about 240 species, are an important group of mesopelagic deep sea fishes in terms of diversity, distribution, and numbers of individuals (Helfman et al., 2009). These species make up a large fraction of the deep scattering layer, so-called because the sonic pulses of a sonar can reflect off the millions of swim bladders, often giving the impression of a false bottom (Moyle & Cech, 2004). Generally, deep-sea fishes are divided into two groups, those that are found in the water column and others associated with the seafloor. In the Study Area, the cookie cutter shark (Dalatiidae), fangtooths (Anoplogastridae), hatchetfishes (Sternoptychidae), and lanternfishes (Myctophidae) inhabit the water column while the seafloor is inhabited with grenadiers or rattails (Macrouridae), hagfishes (Myxinidae), rays (Rajidae), and some rockfishes (Sebastidae).

Some fishes use one habitat type over their entire life cycle, while others associate with different habitat types by life stage. Anadromous fishes such as the steelhead (*Oncorhynchus mykiss*) hatch and rear in freshwater rivers as larvae and early juveniles and inhabit estuaries as they transition into late-juvenile and early sub-adult life stages before entering the ocean to mature into adults. Many other marine fishes inhabit the water column as larvae, settling onto soft bottom habitat as juveniles and remaining there as adults (e.g., flatfishes). The reef-associated Pacific seahorse (*Hippocampus ingens*) and oceanic Pacific bluefin tuna (*Thunnus orientalis*) provide examples of species closely connected to one habitat category across their life cycle.

3.6.2.1.2 Movement and Behavior

Fishes exhibit a rich array of sophisticated behavior (Meyer et al., 2010). Fishes have been shown to cooperate in a variety of ways during foraging, navigation, reproduction, and predator avoidance (Fitzpatrick et al., 2006; Huntingford et al., 2006; Johnstone & Bshary, 2004). Some examples of the common types of behavior exhibited by fishes include movement or migration, schooling, feeding, and resting (Moyle & Cech, 2004).

Migratory behavior consists of mass movements from one place to another and can range in occurrence from daily to seasonal, depending on the species. Tunas, salmon, and eels migrate thousands of miles in short periods of time (e.g., a few months). Daily or seasonal migrations are typically for feeding and/or predator avoidance and can also be referred to as movement patterns. Some common movement patterns include coastal migrations, open ocean migrations, onshore/offshore movements, vertical water column movements, and life stage-related migrations (e.g., eggs and larvae as part of the plankton/nekton). Migratory behavior occurs in response to changing environmental conditions, particularly temperature, or the movement and abundance of food organisms. The destinations of migratory events are often feeding or reproductive grounds. Many fishes have the ability to find their way back to a “home” area and some species use olfactory and visual cues, as well as chemicals released by the other fishes to return home. Highly migratory species such as hammerhead shark (*Sphyrna* species), basking shark (*Cetorhinus maximus*), and swordfish (*Xiphias gladius*), may move across thousands of miles of open ocean. Other migratory species such as the steelhead exhibit seasonal movement patterns throughout coastal continental shelf waters and beyond.

A shoal is defined as any group of fishes that remain together for social reasons, while a school is a polarized, synchronized shoal (Moyle & Cech, 2004), often swimming together in tight formations. Schools can change shape when traveling, feeding, resting, or avoiding predators. Vision and the lateral-line system (defined below in Section 3.6.2.1.3, Hearing and Vocalization) play roles in assisting schooling by allowing fish to visually orientate to one another and also sense water movements when visibility is reduced. Schooling behavior may provide protection against predators. Schooling may also be beneficial in terms of reproduction since little energy has to be expended to find a mate when sexes school together (Moyle & Cech, 2004).

Feeding behavior of fishes is influenced by many factors, including characteristics of the environment, predators, and prey. When food is scarce, individual fish have been observed capturing prey items of all sizes, for which there is likely to be a net gain of energy for the fish. However, when food is abundant, a fish will typically seek the prey item that produces the most energy for the least amount of effort. The body shape of a fish species, specifically the mouth, reflects the general method of feeding. Many fishes must swallow their prey whole and have mouths specialized for their prey depending on the prey’s size and shape (Price et al., 2015). Fishes with their mouth on the underside of their body (e.g., sturgeon, rays, skates, etc.) are typically bottom feeders, while fishes with their mouths near the top of their head (e.g., mullets, halfbeaks, etc.) are typically surface feeders. Fishes that typically feed in the water column, which includes most species, have mouths that are centered in their head. Common types of feeding behavior include ambushing, drift feeding, and filter feeding; fishes may regularly switch between two or more modes of feeding behavior depending on the abundance of prey (Moyle & Cech, 2004).

3.6.2.1.3 Hearing and Vocalization

All fishes have two sensory systems that can detect sound in the water: the inner ear, which functions similarly to the inner ear in other vertebrates, and the lateral line, which consists of a series of receptors along the body of a fish (Popper & Schilt, 2008). The lateral line system is sensitive to external particle motion arising from sources within a few body lengths of the animal. The lateral line detects particle motion at low frequencies from below 1 hertz (Hz) up to at least 400 Hz (Coombs & Montgomery, 1999; Hastings & Popper, 2005; Higgs & Radford, 2013; Webb et al., 2008). Generally, the inner ears of fish contain three dense otoliths (i.e., small calcareous bodies) that sit atop many delicate mechanoelectric hair cells within the inner ear of fishes, similar to the hair cells found in the mammalian ear. Sound waves in water tend to pass through the fish's body, which has a composition similar to water, and vibrate the otoliths. This causes a relative motion between the dense otoliths and the surrounding tissues, causing a deflection of the hair cells, which is sensed by the nervous system.

Although a propagating sound wave contains pressure and particle motion components, particle motion is most significant at low frequencies (up to at least 400 Hz) and is most detectible at high sound pressures or very close to a sound source. The inner ears of fishes are directly sensitive to acoustic particle motion rather than acoustic pressure (acoustic particle motion and acoustic pressure are discussed in Appendix D, Acoustic and Explosive Concepts). Historically, studies that have investigated hearing in, and effects to, fishes have been carried out with sound pressure metrics. Although particle motion may be the more relevant exposure metric for many fish species, there is little data available that actually measures it due to a lack of standard measurement methodology and experience with particle motion detectors (Hawkins et al., 2015; Martin et al., 2016). In these instances, particle motion can be estimated from pressure measurements (Nedelec et al., 2016a).

Some fishes possess additional morphological adaptations or specializations that can enhance their sensitivity to sound pressure, such as a gas-filled swim bladder (Astrup, 1999; Popper & Hastings, 2009a; Popper & Fay, 2011). The swim bladder can enhance sound detection by converting acoustic pressure into localized particle motion, which may then be detected by the inner ear (Radford et al., 2012). Fishes with a swim bladder generally have better sensitivity and can detect higher frequencies than fishes without a swim bladder (Popper & Fay, 2011; Popper et al., 2014). In addition, structures such as gas-filled bubbles near the ear or swim bladder, or even connections between the swim bladder and the inner ear, also increase sensitivity and allow for high-frequency hearing capabilities and better sound pressure detection.

Although many researchers have investigated hearing and vocalizations in fish species (Ladich & Fay, 2013; Popper et al., 2014), hearing capability data only exist for just over 100 of the currently known 34,000 marine and freshwater fish species (Eschmeyer & Fong, 2016). Therefore, fish hearing groups are defined by species that possess a similar continuum of anatomical features, which result in varying degrees of hearing sensitivity (Popper & Hastings, 2009a; Popper & Fay, 2011). (Popper & Fay, 2011)Categories and descriptions of hearing sensitivities are further defined in this document (modified from Popper et al., 2014) as the following:

- Fishes without a swim bladder—hearing capabilities are limited to particle motion detection at frequencies well below 1 kilohertz (kHz).

- Fishes with a swim bladder not involved in hearing—species lack notable anatomical specializations and primarily detect particle motion at frequencies below 1 kHz.
- Fishes with a swim bladder involved in hearing—species can detect frequencies below 1 kHz and possess anatomical specializations to enhance hearing and are capable of sound pressure detection up to a few kHz.
- Fishes with a swim bladder and high-frequency hearing—species can detect frequencies below 1 kHz and possess anatomical specializations and are capable of sound pressure detection at frequencies up to 10 kHz to over 100 kHz.

Data suggest that most species of marine fish either lack a swim bladder (e.g., sharks and flatfishes) or have a swim bladder not involved in hearing and can only detect sounds below 1 kHz. Some marine fishes (clupeiforms) with a swim bladder involved in hearing are able to detect sounds to about 4 kHz (Colleye et al., 2016; Mann et al., 2001; Mann et al., 1997). One subfamily of clupeids (i.e., Alosinae) can detect high- and very high-frequency sounds (i.e., frequencies from 10 to 100 kHz, and frequencies above 100 kHz, respectively), although auditory thresholds at these higher frequencies are elevated and the range of best hearing is still in the low-frequency range (below 1 kHz) similar to other fishes. Mann et al. (1997, 1998) theorize that this subfamily may have evolved the ability to hear relatively high sound levels at these higher frequencies in order to detect echolocations of nearby foraging dolphins. For fishes that have not had their hearing tested, such as deep sea fishes, the suspected hearing capabilities are based on the structure of the ear, the relationship between the ear and the swim bladder, and other potential adaptations such as the presence of highly developed areas of the brain related to inner ear and lateral line functions (Buran et al., 2005; Deng et al., 2011, 2013). It is believed that most fishes have their best hearing sensitivity from 100 to 400 Hz (Popper, 2003).

Species listed under the ESA within the Study Area include the scalloped hammerhead shark (*Sphyrna lewini*), steelhead (*Oncorhychus mykiss*), gulf grouper (*Mycteroperca jordani*), giant manta ray (*Manta birostris*), and the oceanic whitetip shark (*Carcharhinus longimanus*). As discussed above, most marine fishes investigated to date lack hearing capabilities greater than 1,000 Hz. This notably includes steelhead (Song et al., 2006), a species with a swim bladder that is not involved in hearing. Steelhead hearing has only been tested up to 500 Hz (Ladich & Fay, 2013) but likely possess similar hearing ranges to other salmonids (i.e., up to 1 kHz) due to similarities between the inner ear structures and swim bladder morphology. Rays and sharks are cartilaginous fishes (i.e., elasmobranchs) lacking a swim bladder. Available data suggest these species can detect sounds from 20 to 1,000 Hz, with best sensitivity at lower ranges (Casper et al., 2003; Casper & Mann, 2006; Casper & Mann, 2009; Myrberg, 2001). Gulf groupers have a swim bladder that is not involved in hearing. As part of the family Epinephelidae, gulf grouper may have a similar hearing range to the leopard coral grouper (*Plectropomus leopardus*), the larvae of which can detect sounds 100 to 2,000 Hz (Wright et al., 2008; Wright et al., 2010).

Some fishes are known to produce sound. Bony fishes can produce sounds in a number of ways and use them for a number of behavioral functions (Ladich, 2008, 2014). Over 30 families of fishes are known to use vocalizations in aggressive interactions, and over 20 families are known to use vocalizations in mating (Ladich, 2008). Sounds generated by fishes as a means of communication are generally below 500 Hz (Slabbekoorn et al., 2010). The air in the swim bladder is vibrated by the sound producing structures (often muscles that are integral to the swim bladder wall) and radiates sound into the water (Zelick et al., 1999). Sprague and Luczkovich (2004) calculated that silver perch, of the family sciaenidae, can produce drumming sounds ranging from 128 to 135 decibels referenced to 1 micropascal (dB re 1 µPa). Female midshipman fish apparently detect and locate the "hums" (approximately 90 to 400 Hz) of vocalizing males during the breeding season (McIver et al., 2014; Sisneros & Bass, 2003). Sciaenids produce a variety of sounds, including calls produced by males on breeding grounds (Ramcharitar et al., 2001), and a "drumming" call produced during chorusing that suggests a seasonal pattern to reproductive-related function (McCauley & Cato, 2000). Other sounds produced by chorusing reef fishes include "popping," "banging," and "trumpet" sounds; altogether, these choruses produce sound levels 35 dB above background levels, at peak frequencies between 250 and 1,200 Hz, and source levels between 144 and 157 dB re 1 µPa (McCauley & Cato, 2000).

3.6.2.1.4 General Threats

Fish populations can be influenced by various natural factors and human activities. There can be direct effects, from disease or from commercial and recreational activities such as fishing, or indirect effects, such as those associated with reductions in prey availability or lowered reproductive success of individuals. Human-made impacts are widespread throughout the world's oceans, such that very few habitats remain unaffected by human influence (Halpern et al., 2008a). Direct and indirect effects have shaped the condition of marine fish populations, particularly those species with large body size, late maturity ages, or low fecundity such as sharks, Pacific cod (*Gadus macrocephalus*), and Pacific bluefin tuna, making these species especially vulnerable to habitat losses and fishing pressure (Reynolds et al., 2005). Human-induced stressors (e.g., threats) can be divided into four components, which often act on fish populations simultaneously: habitat alteration, exploitation, introduction of non-native species, and pollution (Moyle & Cech, 2004). Climate change and its resulting effects on the marine environment are additional stressors on fish populations.

Coastal development, deforestation, road construction, dam development, water control structures, and agricultural activities are types of habitat alteration that can affect fishes and their environment. These activities may affect the water quality of the nearshore marine environment. Threats to fishes related to poor water quality are discussed in Section 3.6.2.1.4.1 (Water Quality). Threats from exploitation, including commercial and recreational fishing industries and other stressors, are addressed in Section 3.6.2.1.4.2 (Commercial and Recreational Activities). Fishes living in suboptimal conditions from habitat alteration and overexploitation due to fishing may be at increased risk of contracting diseases and acquiring parasites, which are covered in Section 3.6.2.1.4.3 (Diseases and Parasites). The presence of an introduced species represents a major change in the native fish community, and this topic is discussed in Section 3.6.2.1.4.4 (Invasive Species). The threats to fish from oil spills, marine debris, and noise are covered in Section 3.6.2.1.4.1 (Water Quality). Climate change and its effects on fishes are addressed in Section 3.6.2.1.4.5 (Climate Change).

3.6.2.1.4.1 Water Quality

Parameters such as temperature, dissolved oxygen, salinity, turbidity, and pH define the water quality as a component of habitat quality for fishes. Some land-based activities can directly and indirectly impact water quality in rivers, estuaries, and in the coastal waters. Sediment from activities on land may be transported to the marine environment. Sediment can impact water quality by increasing turbidity and decreasing light penetration into the water column, as well as transport contaminants into the marine environment (Allen, 2006). Increases in sediment can decrease the survival and reproduction of plankton and have food web and ecosystem level effects.

Hypoxia (low dissolved oxygen concentration) is a major impact associated with poor water quality. Hypoxia occurs when waters become overloaded with nutrients such as nitrogen and phosphorus, which enter oceans from agricultural runoff, sewage treatment plants, bilge water, and atmospheric deposition. An overabundance of nutrients can stimulate algal blooms, resulting in a rapid expansion of microscopic algae (phytoplankton) and can cause anoxic events leading to fish kills (Corcoran et al., 2013). Over the last several decades, coastal regions throughout the world have experienced an increase in the frequency of algal blooms that are toxic or otherwise harmful. Commonly called red tides, these events are now grouped under the descriptor harmful algal blooms (Anderson et al., 2002). Harmful algal blooms can produce toxins, causing human illness and massive fish and other animal mortalities.

Pollution

Chemicals and debris are the two most common types of pollutants in the marine environment. Information on marine debris is provided below in Section 3.6.2.1.4.6 (Marine Debris). Global oceanic circulation patterns result in the accumulation of a considerable amount of pollutants and debris scattered throughout the open ocean and concentrated in gyres and other places (Crain et al., 2009). Pollution initially impacts fishes that occur near the sources of pollution, but may also affect future generations from effects to reproduction and increased mortality across life stages.

Chemical pollutants in the marine environment that may impact marine fishes include organic pollutants (e.g., pesticides, herbicides, polycyclic aromatic hydrocarbons, flame retardants, and oil) and inorganic pollutants (e.g., heavy metals) (Pew Oceans Commission, 2003). High chemical pollutant levels in marine fishes may cause behavioral changes, physiological changes, or genetic damage (Goncalves et al., 2008; Moore, 2008; Pew Oceans Commission, 2003). Bioaccumulation is the net buildup of substances (e.g., chemicals or metals) in an organism from inhabiting a contaminated habitat or from ingesting food or prey containing the contaminated substance (Newman, 1998), or from ingesting the substance directly (Moore, 2008). Bioaccumulation of pollutants (e.g., metals and organic pollutants) is also a concern to human health because people consume top predators with high pollutant loads.

Oil Spills

Groups of fish typically impacted by oil spills include surface-oriented or surface dwelling species, nearshore (within 3 NM of the shoreline) species, and species whose spawning time coincided with an oil spill (Yender et al., 2010). Fishes can be impacted by the oil directly through the gills, or by consuming oil or oiled prey. Potentially harmful physiological effects to fishes from oil spills include reduced growth, enlarged livers, changes to heart and respiration rate, fin erosion, and reproductive impairment. The most damaging effects of oil on fish populations may be in harming eggs and larvae, because these stages are highly sensitive to oil at the surface, in the water column, or on the seafloor, and are subject to increased mortality and morphological deformities and impaired growth (Greer et al., 2012; Ingvarsdottir et al., 2012; National Oceanic and Atmospheric Administration, 2014; Ocean Conservancy, 2010a; Restore the Gulf, 2010). Discharges from ballast water and bilge water during routine ship operations and illegal dumping of solid waste are other sources of oil in the marine environment.

3.6.2.1.4.2 Commercial and Recreational Activities

Exploitation by commercial and recreational fishing is the single biggest cause of changes in fish populations and communities (Moyle & Cech, 2004). Historic and current overfishing largely contributed to the listing of ESA-protected marine species (Crain et al., 2009; Kappel, 2005). Overfishing of a resource results from both legal and illegal fishing (poaching) and bycatch of resources in quantities above a sustainable level. At the end of 2017, 30 managed fish stocks in the U.S. were on the overfishing list and 35 stocks were on the overfished list, while the number of rebuilt fish stocks since 2000 increased to 44 (National Marine Fisheries Service, 2016a, 2018).

In recent decades, commercial fisheries have targeted the larger, predatory, and sometimes higher-priced fish species. Gradually, this fishing pressure could make the larger species more scarce, and fishing will move towards the smaller species (Pauly & Palomares, 2005). Other factors, such as fisheries-induced evolution and intrinsic vulnerability to overfishing, have been shown to reduce the abundance of some populations (Kauparinen & Merila, 2007). Fisheries-induced evolution is a change in genetic composition of the population that results from intense fishing pressure, such as a reduction in the overall size and growth rates of fishes in a population. Intrinsic vulnerability is when certain life history traits (e.g., large body size, late maturity age, low growth rate, low offspring production) result in a species being more susceptible to overfishing than others (Cheung et al., 2007).

Other threats from commercial industries to fishes include vessel strikes, sea farming, and energy production activities. Large commercial passenger vessels (e.g., cruise liners) pose threats to large, slow-moving open ocean fishes while moving along the sea surface. Whale sharks (*Rhincodon typus*), basking sharks (*Cetorhinus maximus*), sturgeons (Acipenseridae), manta rays (*Manta* spp), and ocean sunfish (*Mola mola*) are vulnerable to ship strikes (National Marine Fisheries Service, 2010a; Rowat et al., 2007; Stevens, 2007).

The threats of aquaculture operations on wild fish populations include reduced water quality, competition for food, predation by escaped or released farmed fishes, spread of disease and parasites, and reduced genetic diversity (Kappel, 2005). These threats become apparent when farmed fish escape and enter the natural ecosystem (Hansen & Windsor, 2006; Ormerod, 2003). The National Oceanic and Atmospheric Administration (2011) published the Marine Aquaculture Policy which provides direction to enable the development of sustainable marine aquaculture.

Energy production and offshore activities associated with power-generating facilities results in direct and indirect injury and/or mortality of fishes. Injury and mortality sources include entrainment of eggs and larvae during water withdrawal and impingement of juveniles and adults (U.S. Environmental Protection Agency, 2004). Acoustic impacts from offshore wind energy development are additional sources of injury and mortality (Madsen et al., 2006).

Anthropogenic Noise

Anthropogenic noise is generated from a variety of sources including commercial shipping, oil and gas exploration and production activities, commercial and recreational fishing (including fish-finding sonar, fathometers, and acoustic deterrent devices), recreational boating, whale watching activities and other marine transportation vessels such as ferries, marine and coastal development (i.e., construction of bridges, ferry terminals, windfarms, etc.), and research (including sound from air guns, sonar, and telemetry). Vessel noise in particular is a major contributor to noise in the ocean and is intensively produced in inland waters. Commercial shipping's contribution to ambient noise in the ocean increased by as much as 12 dB between approximately the 1960s and 2005 (Hildebrand, 2009; McDonald et al., 2008). Frisk (2012) confirmed the trend and reported that between 1950 and 2007 ocean noise in the 25 to 50 Hz frequency range increased 3.3 dB per decade, resulting in a cumulative increase of approximately 19 dB over a baseline of 52 dB (decibels re 1 $\mu Pa^2/Hz$). The increase in noise is associated with an increase in commercial shipping, which correlates with global economic growth (Frisk, 2012). Miksis-Olds and Nichols (2015) found low-frequency ocean sound levels have decreased in the South Atlantic and Equatorial Pacific Oceans, similar to a trend of slightly decreasing low-frequency noise levels in the Northeast Pacific. In addition to vessels, other sources of underwater noise include pile-driving activity (Carlson et al., 2007; Casper et al., 2012b; Casper et al., 2013a; Casper et al., 2013b; Dahl et al., 2015; Debusschere et al., 2014; Feist et al., 1992; Halvorsen et al., 2012b; Popper et al., 2006;

Ruggerone et al., 2008; Stadler & Woodbury, 2009), sonar (California Department of Transportation, 2001; Carlson et al., 2007; Mueller-Blenkle et al., 2010; Popper et al., 2006), seismic activity (Popper & Hastings, 2009b), and offshore construction projects (Foderaro, 2015).

Noise can cause permanent injury in some marine animals (Popper et al., 2005). Physiological responses to noise have shown a variety of results. For example, the giant kelpfish (*Heterostichus rostratus*) exhibited acute stress response when exposed to intermittent recorded boat engine noise (Nichols et al., 2015). In another study, Holles et al. (2013) found that local, low-intensity noise from recreational boat engines has the capacity to disrupt settlement in coral reef fish larvae, which may lead to impacts on recruitment to adult populations.

3.6.2.1.4.3 Disease and Parasites

Fishes in poor quality environments have higher incidences of disease, due to increased stress levels and decreased immune system function, and are less resilient to fight the disease. Parasites, bacteria, aquaculture conditions, environmental influences, and poor nourishment contribute to fish disease levels (National Oceanic and Atmospheric Administration, 2016d). Disease outbreaks in fishes are influenced by environmental conditions, which typically are more variable in inland waters compared to the open ocean (Snieszko, 1978). Areas with higher density fish populations, such as marine protected areas and fish farms, are at higher risk for disease compared to areas with lower densities (National Oceanic and Atmospheric Administration, 2016b; Wootton et al., 2012). Additionally, introduced species may expose native species to new diseases and parasites. In Hawaii, the introduction of the bluestripe snapper (*Lutjanus kasmira*) native to the Indian Ocean introduced a parasitic nematode (*Spirocamallanus istiblenni*) that has spread to native fish species (Gaither et al., 2013).

3.6.2.1.4.4 Invasive Species

Native fish populations are affected by invasive (introduced, non-native) species by predation, competition and hybridization (Moyle & Cech, 2004). Non-native fishes pose threats to native fishes when they are introduced into an environment lacking natural predators and then either compete with native marine fishes for resources or prey upon the native marine fishes (Crain et al., 2009). Marine invasions by other non-fish species also may impact fish populations. Invasive marine algae have been found to alter the health status of native fishes feeding on the algae, which could impact the reproduction success of those populations (Felline et al., 2012).

In the Study Area, some of the invasive species include the peacock grouper (*Cephalopholis argus*), introduced to Hawaii, the yellowfin goby (*Acanthogobius flavimanus*), and the rainwater killifish (*Lucania parva*). The yellowfin goby is native to eastern Asia and the rainwater killifish is native to the U.S. Atlantic coast. Both of these fishes have also been introduced to the San Diego Bay (Gaither et al., 2013).

3.6.2.1.4.5 Climate Change

Global climate change is impacting and will continue to impact marine and estuarine fish and fisheries (Intergovernmental Panel on Climate Change, 2014; Roessig et al., 2004). Climate change is contributing to a shift in fish distribution from lower to higher latitudes (Brander, 2010; Brander, 2007; Dufour et al., 2010; Popper & Hastings, 2009b; Wilson et al., 2010). Warming waters over the past quarter-century have driven fish populations in the northern hemisphere northward and to deeper depths (Inman, 2005). (Asch, 2015; 2012; Heuer & Grosell, 2014; Peterson et al., 2014)

Fishes with shifting distributions have faster life cycles and smaller body sizes than non-shifting species (Perry et al., 2005). In addition to affecting species ranges, increasing temperature has been shown to alter the sex-ratio in fish species that have temperature-dependent sex determination mechanisms (Ospina-Alvarez & Piferrer, 2008). Further temperature rises are likely to have profound impacts on commercial fisheries through continued shifts in distribution and alterations in community interactions (Perry et al., 2005). It appears that diadromous and benthic fish species are most vulnerable to climate change impacts (Hare et al., 2016).

Ocean acidification, the process whereby increasing atmospheric carbon dioxide concentrations reduces ocean pH and carbonate ion concentrations, may have serious impacts on fish development and behavior (Raven et al., 2005). Physiological development of fishes can be affected by increases in pH that can increase the size, density, and mass of fish otoliths (e.g., fish ear stones), which would affect sensory functions (Bignami et al., 2013). Ocean acidification may affect fish larvae behavior and could impact fish populations (Munday et al., 2009). A range of behavioral traits critical to survival of newly settled fish larvae are affected by ocean acidification. Settlement-stage larval marine fishes exposed to elevated carbon dioxide were less responsive to threats than controls. This decrease in sensitivity to risk might be directly related to the impaired olfactory ability (Munday et al., 2009).

Beyond direct impacts on fishes from increasing pH, ocean acidification can cause changes to the ocean chemistry, which leads to increased algal blooms (Anderson et al., 2002). Ocean acidification can also lead to reef impacts, such as coral bleaching, and can also lead to reduced larval settlement and abundance (Doropoulos et al., 2012). Plankton are important prey items for many fish species and are also impacted by ocean acidification. Ocean acidification may cause a shift in phytoplankton community composition and biochemical composition that can impact the transfer of essential compounds to predators that eat the plankton (Bermudez et al., 2016) and can cause shifts in community composition.(Anderson et al., 2002; Bermudez et al., 2016; Doropoulos et al., 2012; Fabry et al., 2008; Kroeker et al., 2013)

Another climate change effect is ocean deoxygenation. Netburn and Koslow (2015) found that the depth of the lower boundary of the deep scattering layer (so-called because the sonic pulses of a sonar can reflect off the millions of fish swim bladders) is most strongly correlated with dissolved oxygen concentration, and irradiance and oxygen concentration are the key variables determining the upper boundary. This study estimated the corresponding annual rate of change of deep scattering layer depths and hypothesized that if past trends continue, the upper boundary is expected to rise at a faster rate than the lower boundary, effectively widening the deep scattering layer. Cao et al. (2014) modeled different sensitivities of ocean temperature, carbonate chemistry, and oxygen, in terms of both the sign and magnitude to the amount of climate change. Model simulations in this study found by the year 2500, every degree increase of climate sensitivity will warm the ocean by 0.8 °C and will reduce ocean-mean dissolved oxygen concentration by 5.0 percent. Conversely, every degree increase of climate sensitivity buffers CO_2-induced reduction in ocean-mean carbonate ion concentration and pH by 3.4 percent and 0.02 units, respectively. These results have great implications for understanding the response of ocean biota to climate change. Keller et al. (2015) suggested that within the California Current System, shoaling of the oxygen minimum zone is expected to produce complex changes and onshore movement of the oxygen minimum zone could lead to habitat compression for species with higher oxygen requirements while allowing expansion of species tolerant of low bottom dissolved oxygen.

3.6.2.1.4.6 Marine Debris

Marine debris is a widespread global pollution problem, and trends suggest that accumulations are increasing as plastic production rises (Rochman et al., 2013). Debris includes plastics, metals, rubber, textiles, derelict fishing gear, vessels, and other lost or discarded items. Debris such as abandoned nets and lines also pose a threat to fishes. Due to body shape, habitat use, and feeding strategies, some fishes are more susceptible to marine debris entanglement than others (Musick et al., 2000; Ocean Conservancy, 2010b). Entanglement in abandoned commercial and recreational fishing gear has caused declines for some marine fishes.

Microplastics (i.e., plastics less than 5mm in size) in the marine environment are well documented, and interactions with marine biota, including numerous fish species have been described worldwide (Lusher et al., 2016). Plastic waste in the ocean chemically attracts hydrocarbon pollutants such as polychlorinated biphenyl (PCB) and dichlorodiphenyltrichloroethane, which accumulate up to one million times more in plastic than in ocean water (Mato et al., 2001). Fishes can mistakenly consume these wastes containing elevated levels of toxins instead of their prey. Rochman et al., (2015) found marine debris in 28 percent of the individual fish examined and in 55 percent of all fish species analyzed. According to the California Coastal Commission, only 20 percent of the items found in the ocean can be linked to ocean-based sources, like commercial fishing vessels, cargo ships (discharge of containers and garbage), or pleasure cruise ships, while 80 percent of the debris is land based from sources like litter, industrial discharges, and garbage management (California Coastal Commission, 2018).

3.6.2.2 Endangered Species Act-Listed Species

In the Study Area, three fish species are listed as endangered, the Eastern Pacific distinct population segment of the scalloped hammerhead shark, the Southern California Coast distinct population segment of steelhead, and the gulf grouper. Additionally, two fish are listed as threatened—the giant manta and oceanic whitetip shark (Table 3.6-1).

In addition to the aforementioned listed species, fish species that are under consideration for listing can be broken into two categories: candidates for listing and proposed for listing. Candidate species are any species that are undergoing a status review that have been announced in a *Federal Register* notice. Proposed species are those candidate species that were found to warrant listing as either threatened or endangered and were officially proposed as such in a *Federal Register* notice after the completion of a status review and consideration of other protective conservation measures. There are currently no candidate or proposed fish species that occur in the Study Area.

NMFS also manages a proactive conservation program that allows for species for which there are concerns regarding status and threats, but for which insufficient information is available to indicate a need for listing the species under the ESA. These species are listed as “species of concern.” Within the Study Area, there are three fish species listed as species of concern: the basking shark (*Cetorhinus maximus*), bocaccio (*Sebastes paucispinis*), and cowcod (*S. levis*) (Table 3.6-1). As the species of concern are not considered for listing at this time, they will not be discussed further in this document.

3.6.2.2.1 Scalloped Hammerhead Shark (*Sphyrna lewini*)

3.6.2.2.1.1 Status and Management

The Eastern Pacific distinct population segment of the scalloped hammerhead population is listed as endangered under the ESA. There is no designated critical habitat within the Study Area.

3.6.2.2.1.2 Habitat and Geographic Range

The scalloped hammerhead shark is a coastal and semi-oceanic species distributed in temperate and tropical waters (Froese & Pauly, 2016). Scalloped hammerhead sharks inhabit the surface to depths of

Table 3.6-1: Regulatory Status and Occurrence of Endangered Species Act-Listed Fishes in the Study Area

Regulatory Status[1]			Occurrence in the Study Area		
Common Name	**Scientific Name**	**Endangered Species Act Status**	**Open Ocean**	**Large Marine Ecosystem**	**Inshore Waters**
Scalloped (Hammerhead *(Eastern Pacific DPS*)	*Sphyrna lewini*	Endangered	NA	California Current	NA
Steelhead (*Southern California Coast DPS*)	*Oncorhynchus mykiss*	Endangered	NA	California Current	NA
Gulf Grouper	*Mycteroperca jordani*	Endangered	NA	California Current	NA
Giant Manta Ray	*Manta birostris*	Threatened	North Pacific Gyre	California Current; Insular Pacific-Hawaii	NA
Oceanic Whitetip Shark	*Carcharhinus longimanus*	Threatened	North Pacific Gyre	California Current	NA
Basking Shark	*Cetorhinus maximus*	Species of Concern	NA	California Current	NA
Bocaccio	*Sebastes paucispinis*	Species of Concern	NA	California Current	NA
Cowcod	*Sebastes levis*	Species of Concern	NA	California Current	NA

[1] Species of concern status do not carry any procedural or substantive protections under the ESA, but are provided for informational purposes.
Notes: NA = not applicable, DPS = Distinct Population Segment

275 m (Duncan & Holland, 2006) of the Study Area. Inland waters with temperatures between 23° and 26°C are preferred habitats (Castro, 1983; Compagno, 1984), with animals generally remaining close to shore during the day and moving into deeper waters to feed at night (Bester, 1999). Ketchum et al. (2014a) found scalloped hammerheads formed daytime schools at specific locations in the Galapagos Islands, but dispersed at night, spending more time at the northern islands during part of the warm season (December–February) compared to the cool. Ketchum et al. (2014b) used acoustic telemetry to show that scalloped hammerheads were highly selective of location (i.e., habitat on up-current side of island) and depth (i.e., top of the thermocline) while refuging, where they may carry out essential activities such as cleaning and thermoregulation, and also perform exploratory vertical movements by diving the width of the mixed layer and occasionally diving below the thermocline while moving offshore, most likely for foraging. Hoffmayer et al. (2013) also found that tagged sharks exhibited consistent and repeated diel vertical movement patterns, making more than 76 deep nighttime dives to a maximum depth of 964 m, possibly representing feeding behavior. A genetic marker study suggests that females remain close to coastal habitats, while males disperse across larger open ocean areas (Daly-Engel et al., 2012).

In the eastern Pacific, their range extends from southern California (including the Gulf of California) to Panama, Ecuador, and northern Peru, and includes waters off Hawaii and Tahiti (Bester, 1999). Juveniles rear in coastal nursery areas (Duncan & Holland, 2006), but rarely inhabit the open ocean (Kohler & Turner, 2001). In the Insular-Hawaiian Large Marine Ecosystem, neonates, young-of-the-year, and juveniles depend on coastal nursery areas in and around Kaneohe Bay located on Oahu (Duncan & Holland, 2006). Sub-adults and adults occur over shelves and adjacent deep waters close to shore and entering bays and estuaries (Compagno, 1984). Scalloped hammerhead sharks are rare in offshore areas of Southern California, with only a few sightings and landings documented in San Diego Bay in 1981, 1996, and 1997 (Shane, 2001).

3.6.2.2.1.3 Population Trends

The scalloped hammerhead shark has undergone substantial declines throughout its range (Baum et al., 2003). There is some evidence of population increases in some areas of the southeast U.S., such as the Gulf of Mexico (Ward-Paige et al., 2012), but because many catch records do not differentiate between the hammerhead species, or shark species in general. Therefore, population estimates and commercial or recreational fishing landing data for the Eastern Pacific distinct population segment are unavailable in the Study Area.

3.6.2.2.1.4 Predator and Prey Interactions

Scalloped hammerhead sharks have few predators. Sharks locate potential prey by odor, particularly from injured prey, or low-frequency sounds, inner ear (vibrations), and lateral line (turbulence) with vision coming into play at closer range (Moyle & Cech, 2004). They feed primarily at night (Compagno, 1984) on a wide variety of fishes such as sardines, herring, anchovies, and jacks, and also feed on and invertebrates, including squid, octopus, shrimp, crabs, and lobsters (Bester, 1999).

3.6.2.2.1.5 Species-Specific Threats

The primary threat to the scalloped hammerhead shark is direct take, especially by the foreign commercial shark fin fishery (Miller et al., 2014; National Marine Fisheries Service, 2011). Scalloped hammerheads are a principal component of the total shark bycatch in the swordfish and tuna longline fishery and are particularly susceptible to overfishing and bycatch in gillnet fisheries because of schooling habits (Food and Agriculture Organization of the United Nations, 2013). Longline mortality for this species is estimated between 91 and 94 percent (National Marine Fisheries Service, 2011).

3.6.2.2.2 Steelhead (*Oncorhynchus mykiss*)

3.6.2.2.2.1 Status and Management

Steelhead is an anadromous form of rainbow trout and is federally protected by the designation of distinct population segments. Of the 15 steelhead distinct population segments, 2 are listed as endangered, 9 are listed as threatened, and 1 is an ESA species of concern (National Marine Fisheries Service, 2010b). NMFS listed the Southern California distinct population segment of steelhead as endangered in 1997 (National Marine Fisheries Service, 1997). The Southern California Coast distinct population segment range for steelhead extends from Santa Maria River south to San Mateo Creek and includes streams south of Malibu Creek, specifically Topanga and San Mateo Creeks (National Marine Fisheries Service, 2002). The lower portion of San Mateo Creek flows through Marine Corps Base Camp Pendleton and into the Southern California portion of the Study Area. (Hovey, 2004)

Critical habitat includes areas occupied by steelhead at the time of listing and include rivers and estuaries of San Juan Creek, Trabuco Creek, and San Mateo Creek (Figure 3.6-1) which provides spawning and rearing habitats and provides migration corridors. In addition, NMFS has not designated critical habitat for steelhead in nearshore marine areas or offshore marine areas in the Study Area. Even though critical habitat for steelhead is only in freshwater locations just outside the Study Area boundaries, it is possible that adult steelhead may be found in the Study Area.

3.6.2.2.2.2 Habitat and Geographic Range

The natural range of anadromous steelhead includes the Pacific coast of the United States to Southern California (Good et al., 2005), but it is being introduced throughout the world.

Spawning and rearing habitat are not described since both occur outside of the Study Area (2012). Adult steelhead can migrate up to 930 miles from their ocean habitats to reach their freshwater spawning grounds in high elevation tributaries. In the Southern California portion of the Study Area, the primary rivers that steelhead migrate into are the Santa Maria, Santa Ynez, Ventura, and Santa Clara Rivers (Good et al., 2005), although some of these rivers contain considerable migration barriers such as dams. Steelhead hatch in freshwater streams, where they spend their first one to three years. They later move into the ocean, where most of their growth occurs. After spending between one and four years in the ocean, steelhead return to their home freshwater stream to spawn. Unlike other species of Pacific salmon, steelhead do not necessarily die after spawning and are able to spawn more than once. Steelhead may exhibit either an anadromous lifestyle or they may spend their entire life in freshwater (McEwan & Jackson, 1996). The name steelhead is used primarily for the anadromous form of this species.

There is considerable variation in this life history pattern within the population, partly due to Southern California's variable seasonal and annual climatic conditions. Some winters produce heavy rainfall and flooding, which allow juvenile steelhead easier access to the ocean, while dry seasons may close the mouths of coastal streams, limiting juvenile steelheads' access to marine waters (National Marine Fisheries Service, 1997).

3.6.2.2.2.3 Population Trends

Steelhead stocks have declined substantially from their historic numbers and many now are threatened with extinction. Native lineages have been nearly extirpated from the southern region of the native range, with only a few relict populations persisting in the headwaters of the San Gabriel, Santa Ana, and San Luis Rey rivers (National Marine Fisheries Service, 2016b). Abadia-Cardoso et al. (2016) documented that the majority of steelhead sampled between southern California watersheds and Mexico were genetically related to hatchery rainbow trout. This may indicate either replacement of native steelhead or hybridization with native steelhead in Southern California.

Most of the steelhead distinct population segments, including the Southern California Coast distinct population segment, have a low abundances relative to historical levels, and there is widespread occurrence of hatchery fish in naturally spawning populations (Good et al., 2005; National Marine Fisheries Service, 2010b, 2012). NMFS has reported population sizes from individual distinct population segments, but because all of these units occur together while at sea, it is difficult to estimate the marine population numbers.

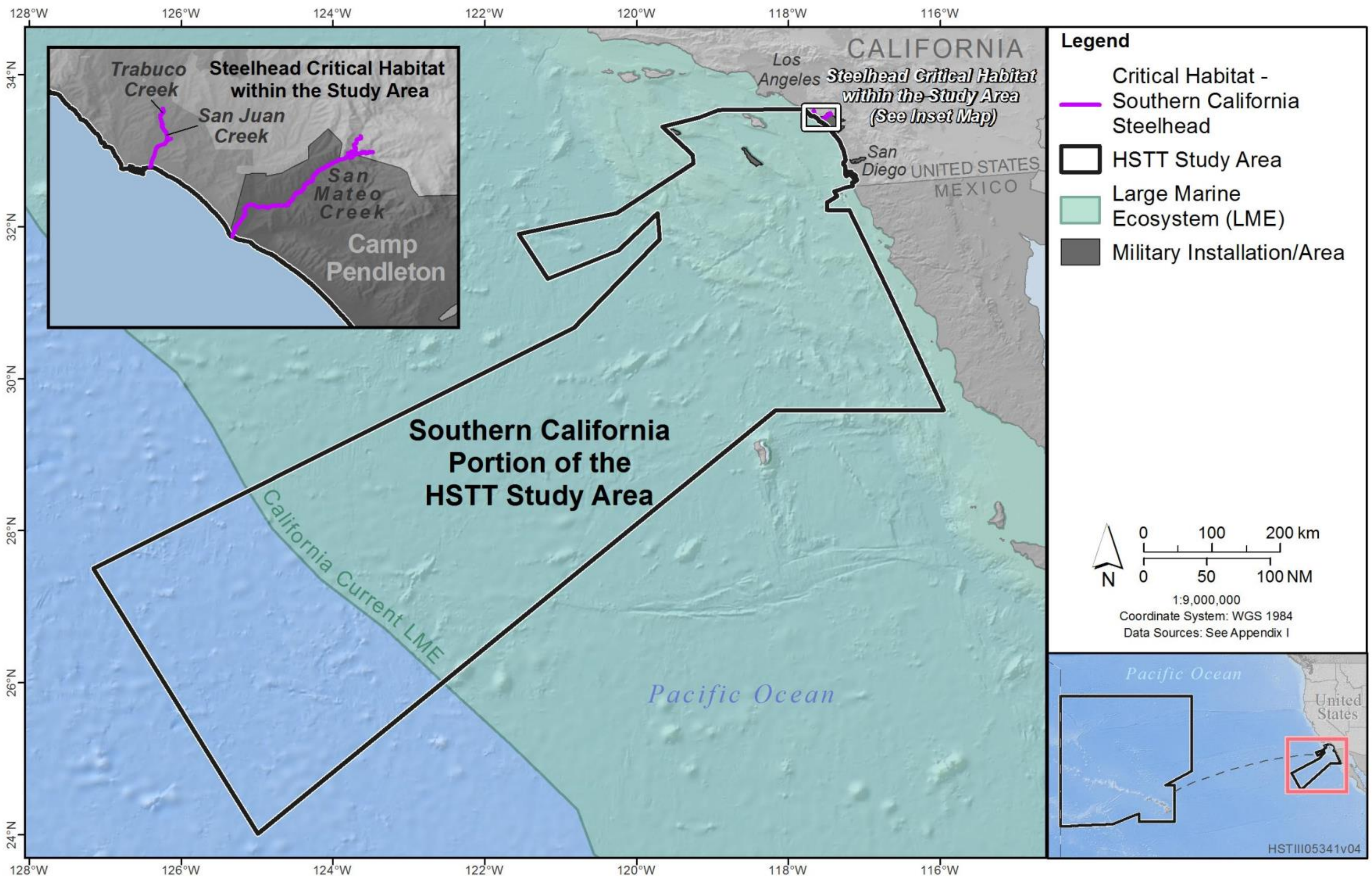


Figure 3.6-1: Critical Habitat Areas for Southern California Coast Steelhead in and Adjacent to the Study Area

Note: HSTT = Hawaii-Southern California Training and Testing

3.6.2.2.2.4 Predator and Prey Interactions

Steelhead predators include birds, such as terns and cormorants, and marine mammals, such as sea lions and harbor seals (National Marine Fisheries Service, 2010b). Juveniles in freshwater feed mostly on zooplankton (small animals that drift in the water), while adults feed on aquatic and terrestrial insects, molluscs, crustaceans, fish eggs, minnows, and other small fishes, including other trout and salmon depending on whether they are inhabiting streams or the ocean (National Marine Fisheries Service, 2010b).

3.6.2.2.2.5 Species-Specific Threats

Most of the threats to Southern California steelhead occur outside the Study Area and include alteration of stream flow patterns and habitat degradation, barriers to fish passage, channel alterations, water quality problems, non-native fishes and plants, and climate change.

3.6.2.2.3 Gulf Grouper (*Mycteroperca jordani*)

3.6.2.2.3.1 Status and Management

The gulf grouper was listed by NMFS as endangered in 2016 (81 *Federal Register* 72545). Not enough information is known about the gulf grouper to determine if it can be broken down into distinct population segments (Dennis, 2015). No critical habitat has been designated for this species.

3.6.2.2.3.2 Habitat and Geographical Range

The gulf grouper is found in the subtropical eastern Pacific Ocean and Gulf of California, from La Jolla, California, to Mazatlán, Sinaloa, Mexico (Dennis, 2015). Adults inhabit rocky reefs, seamounts, and kelp beds at depths between 30 and 45 m (Dennis, 2015).

Requirements for habitat of the gulf grouper varies throughout its life. Not much is known about gulf grouper settlement, recruitment, or growth. However, most groupers exhibit similarities during early life stages, with eggs developing into larvae, then drifting with the ocean currents from their spawning aggregation to settlement habitats, such as seagrass areas and mangroves. Juveniles remain in these areas for up to two years before moving offshore to rocky reefs. Once a year gulf grouper aggregate to spawn during a full moon in May at known locations (Dennis, 2015).

3.6.2.2.3.3 Population Trends

Gulf grouper is a long-lived, late-maturing bony fish inhabiting nearshore shallow tropical and warm temperate marine waters. In the 1930s, there were observations of gulf groupers along the San Diego coastline. The fishery peaked in California during the early 1950s and disappeared by 1970. Observations of gulf grouper in the Gulf of California are more common than sightings in historical southern California fishing grounds (Dennis, 2015). The gulf grouper was once considered abundant, but they are now considered rare, with current abundances likely less than 1 percent of their historical levels (National Marine Fisheries Service, 2017).

3.6.2.2.3.4 Predator and Prey Interactions

Gulf groupers are solitary predators and little is known about their diet. It’s assumed that gulf grouper have similar diets to other grouper species, with juveniles consuming mostly crustaceans. As the young grouper grow in size and age, their diet shifts away from crustaceans such as crab and lobster towards more fishes. Prey items for adults include fishes, slipper lobster, and juvenile hammerhead shark. Because of their large size, predation on gulf grouper decreases with age (Dennis, 2015).

3.6.2.2.3.5 Species-Specific Threats

Current population threats include direct harvest, bycatch in other targeted fisheries, habitat loss and degradation, and climate change impacts on rocky and coral reef ecosystems (Dennis, 2015; National Marine Fisheries Service, 2017). Recreational fisheries outside of the U.S. occur throughout the range of the gulf grouper, and it also is incidentally taken by shrimp-trawlers in the Gulf of California (Craig et al., 2008). The abundance of the gulf grouper has been greatly reduced, especially in aggregation sites, because of bycatch in the commercial shrimp industry. The impact of climate change on increasing ocean temperatures and acidity will continue to contribute to the loss of coral habitat in the gulf grouper range (Dennis, 2015). Human population growth and development has resulted in the loss and degradation of habitat throughout the gulf grouper’s range (Dennis, 2015). Specifically, growth and development in the Gulf of California has reduced fresh water inputs, increased pollution, and degraded or destroyed habitats. Increased ocean temperatures from climate change can also impact the gulf grouper by changing its habitat and that of its predators and prey (Dennis, 2015). Ocean acidification can also lead to coral bleaching and mortality and impacts on fish (egg and larval development) survival.

3.6.2.2.4 Giant Manta Ray (*Manta birostris*)

3.6.2.2.4.1 Status and Management

The giant manta ray was listed as a threatened species under the ESA by NMFS on January 12, 2018 (83 *Federal Register* 2916). NMFS also found that that critical habitat for the giant manta ray is not determinable due to the lack of sufficient data to perform the required analyses.

3.6.2.2.4.2 Habitat and Geographic Range

Giant manta rays are visitors to productive coastlines with regular upwelling, including oceanic island shores, and offshore pinnacles and seamounts. They utilize sandy bottom habitat and seagrass beds, as well as shallow reefs, and the ocean surface both inshore and offshore. The species ranges globally and is distributed in tropical, subtropical, and temperate waters. They migrate seasonally usually more than 1,000 km (621.4 mi.), however not likely across ocean basins (National Oceanic and Atmospheric Administration, 2016c).

Giant manta rays are found throughout the Hawaiian Islands, but large aggregations are known to occur along the Kona coast off the Big Island of Hawaii, with hundreds of individuals participating in the aggregation (Defenders of Wildlife, 2015b). These aggregations are likely timed to peak seasonal abundances of prey such as zooplankton. Southern California is the northern edge of the giant manta ray’s distribution in the California Current Large Marine Ecosystem (Defenders of Wildlife, 2015b).

3.6.2.2.4.3 Population and Trends

No stock assessments exist for the giant manta ray. Most estimates of subpopulations are based on anecdotal observations by divers and fishermen, with current numbers estimated between 100 and 1,500 individuals (Miller & Klimovich, 2016). In general, giant manta ray populations have declined, except in areas where they are specifically protected, such as the Hawaiian Islands (National Oceanic and Atmospheric Administration, 2016c). Giant manta rays reach maturity at age 10 and have one pup every two to three years (National Oceanic and Atmospheric Administration, 2016c).

3.6.2.2.4.4 Predator and Prey Interactions

Manta rays prey exclusively on plankton (Defenders of Wildlife, 2015b). The gill plates of the giant manta ray filters the water as they swim, straining out any plankton that is larger than a grain of sand (Defenders of Wildlife, 2015b).

3.6.2.2.4.5 Species-Specific Threats

Threats to giant manta rays include fisheries and bycatch, destruction or modification of habitat, and disease and predation. The international market highly values the gill plates of the giant manta ray for use in traditional medicines. They also trade their cartilage and skins and consume the manta ray meat or use it for local bait. Bycatch occurs in purse seine, gillnet, and trawl fisheries as well (National Oceanic and Atmospheric Administration, 2016c). Fisheries exist outside the Study Area in Indonesia, Sri Lanka, India, Peru, Mexico, China, Mozambique, and Ghana (Food and Agriculture Organization of the United Nations, 2013). Other potential threats include degradation of coral reefs, interaction with marine debris, marine pollution, and boat strikes (Food and Agriculture Organization of the United Nations, 2013).

3.6.2.2.5 Oceanic Whitetip Shark (*Carcharhinus longimanus*)

3.6.2.2.5.1 Status and Management

The oceanic whitetip shark was listed as threatened under the ESA by NMFS on January 30, 2018 (83 *Federal Register* 4153). NMFS also concluded that critical habitat is not determinable at this time because sufficient information is not currently available to assess the impacts of designation or regarding physical and biological features essential to the conservation of this species.

3.6.2.2.5.2 Habitat and Geographic Range

Oceanic whitetip sharks are found worldwide in warm tropical and subtropical waters between the 30° North and 35° South latitude near the surface of the water column (Young et al., 2016). Oceanic whitetips occur throughout the Central Pacific, including the Hawaiian Islands south to Samoa Islands, and in the eastern Pacific from southern California to Peru, including the Gulf of California. This species has a clear preference for open ocean waters, with abundances decreasing with greater proximity to continental shelves. Preferring warm waters near or over 20°C (68°F), and offshore areas, the oceanic whitetip shark is known to undertake seasonal movements to higher latitudes in the summer (National Oceanic and Atmospheric Administration, 2016a) and may regularly survey extreme environments (deep depths, low temperatures) as a foraging strategy (Young et al., 2016).

3.6.2.2.5.3 Population and Trends

Population trend information is not clear or available. Information shows that the population has declined and that there is evidence of decreasing average weights of the sharks that have been encountered. For example, unstandardized nominal catch data from the Inter-American Tropical Tuna Commission in the eastern Pacific tropical tuna purse seine fisheries show trends of decreasing catch (Inter-American Tropical Tuna Commission, 2015). In addition, Rice & Harley (2012) found catch, catch per unit effort, and size composition data for oceanic whitetip sharks in the western and central Pacific all show consistent declines.

3.6.2.2.5.4 Predator and Prey Interactions

As one of the major apex predators in the tropical open ocean waters, the oceanic whitetip shark feeds on fishes and cephalopods. Oceanic whitetip sharks are large, often reaching a maximum length of 345 cm (Ebert et al., 2015), can live up to nine years (Joung et al., 2016). With its large size and long life, this species can build up high levels of pollutants due to bioaccumulation and biomagnification, impacting their physiology negatively (Defenders of Wildlife, 2015b).

3.6.2.2.5.5 Species-Specific Threats

Threats include pelagic longline and drift net fisheries bycatch, targeted fisheries (for the shark fin trade), and destruction or modification of its habitat and range (Baum et al., 2015; Defenders of Wildlife, 2015a). Legal and illegal fishing activities have caused significant population declines for the oceanic whitetip shark. It is caught as bycatch in tuna and swordfish longlines throughout its range. Habitat degradation has occurred due to pollutants in the environment that bioaccumulate and biomagnify to high levels in their bodies due to their high position in the food chain, long life, and large size (Defenders of Wildlife, 2015a).

3.6.2.3 Species Not Listed Under the Endangered Species Act

Taxonomic categories of major fish groups are provided in Table 3.6-2 and described further in this section to supplement information on fishes of the Study Area that are not ESA-protected species. These fish groups are based on the organization presented by Moyle and Cech (2004), Nelson (2006), Helfman et al. (2009), and Froese and Pauly (2016). These groupings are intended to organize the extensive and diverse list of fishes that occur in the Study Area and serve as a means to structure the analysis of potential impacts on fishes with similar physiological characteristics and habitat use. Exceptions to these generalizations exist within each group and are noted wherever appropriate in the analysis of potential impacts. For simplicity, the fishes are presented in generally accepted evolutionary order.

Table 3.6-2: Major Taxonomic Groups of Fishes in the Hawaii-Southern California Training and Testing Study Area

Major Fish Groups			*Occurrence in the Study Area*	
Group Names	***Description***	***Representative Species***	***Open Ocean***	***Coastal Waters ****
Jawless Fishes (Orders Myxiniformes and Petromyzontiformes)	Primitive, cartilaginous, eel-like vertebrates; parasitic or feed on dead fish	Hagfishes, Lamprey	Seafloor	Water column, seafloor
Ground Sharks, Mackerel Sharks and Bullhead Sharks (Orders Carcharhiniformes, Lamniformes, Orectolobiformes, and Heterdontiformes)	Cartilaginous, two dorsal fins or first large, an anal fin, and five gill slits	Great white, Horn, Oceanic whitetip, Scalloped hammerhead, whale sharks, Tiger sharks	Water column, seafloor	Water column
Frilled and Cow Sharks, Sawsharks, Dogfish, and Angel Sharks (Orders Hexanchiformes, Squaliformes, and Squatiniformes)	Cartilaginous, anal fin and nictitating membrane absent, 6-7 gill slits	Dogfish, Frill, Sevengill, Sixgill sharks	Water column, seafloor	Seafloor
Stingrays, Sawfishes, Skates, Guitarfishes, Electric Rays and Rays (Orders Myliobatiformes, Pristiformes, Rajiformes, and Torpediniformes)	Cartilaginous, flat-bodied, usually 5 gill slits	Electric, Giant Manta rays, Skates, Stingrays	Water column, seafloor	Water column, seafloor
Ratfishes (Order Chimaeriformes)	Cartilaginous, placoid scales	Chimaera, Rabbitfish, Ratfishes	Seafloor	NA
Herrings and allies (Order Clupeiformes)	Silvery, lateral line on body and fin spines absent, usually scutes along ventral profile	Anchovies, Herrings, Sardines	NA	Surface, water column

Table 3.6-2: Major Taxonomic Groups of Fishes in the Hawaii-Southern California Training and Testing Study Area (continued)

Major Fish Groups			*Occurrence in the Study Area*	
Group Names	***Description***	***Representative Species***	***Open Ocean***	***Coastal Waters ****
Tarpons and allies (Orders Elopiformes and Albuliformes)	Body encased in silvery scales, mouth large, mostly a single dorsal fin, some with tapered tail fin, spines absent	Bonefishes, Ladyfish, Malacho, Tarpons	Water column, seafloor	Surface, water column, seafloor
Eels and allies (Orders Anguilliforms, Notacanthiformes, and Saccopharyngiformes)	Body very elongate, usually scaleless with pelvic fins and fin spines absent	American, Conger, Cutthroat, Duckbill, Halosaur, Morays, Pike, Sawtooth, Short-tailed, Spiny, Gulper, Pelican	Water column, seafloor	Water column, seafloor
Salmonids (Orders Salmoniformes)	Silvery body, adipose fin present	Steelhead	NA	Surface, water column
Argentines and allies (Order Argentiniformes)	Body silvery, and elongate; fin spines absent; adipose fin sometimes present, pelvic fins and ribs sometimes absent	Barreleyes, Deep sea smelts, Slickheads, Tubeshoulders	Water column, seafloor	NA
Bristlemouths and allies (Orders Stomiiformes)	Photophores present, adipose and chin barbels fin sometimes present	Dragonfishes, Fangjaws, Hatchetfishes, Lightfishes	Water column, seafloor	NA
Greeneyes and allies (Order Aluopiformes)	Upper jaw protrusible adipose fin present, forked tail usually present	Barracudinas, Daggertooth, Greeneyes, Lizardfishes, Pearleyes, Waryfishes	Surface, water column, seafloor	NA
Lanternfishes and allies (Order Myctophiformes)	Small-sized, adipose fin, forked tail and photophores usually present	Lanternfishes	Water column, seafloor	NA

Table 3.6-2: Major Taxonomic Groups of Fishes in the Hawaii-Southern California Training and Testing Study Area (continued)

Major Fish Groups			*Occurrence in the Study Area*	
Group Names	***Description***	***Representative Species***	***Open Ocean***	***Coastal Waters ****
Hakes and allies (Order Gadiformes)	Long dorsal and anal fins; no true spines, spinous rays present in dorsal fin, barbels present	Cods, Codlings, Grenadiers, Hakes, Whiptails	Water column, seafloor	Surface, water column, seafloor
Brotulas and allies (Order Ophidiiformes)	Pelvic absent or far forward and filamentous, no sharp spines, Dorsal and anal fins joined to caudal fins	Brotulas, Cusk-eels	Water column, seafloor	Water column, seafloor
Toadfishes and allies (Order Batrachoidiformes)	Body compressed; head large; mouth large with tentacles; two dorsal fins, the first with spines	Toadfish, Midshipman	NA	Seafloor
Anglerfishes and allies (Order Lophiiformes)	Body globulose, first spine on dorsal fin usually modified, pelvic fins usually absent	Anglerfishes, Footballfishes, Frogfishes, Goosefishes, Sea devils	Water column, seafloor	Seafloor
Flyingfishes(Order Beloniformes)	Jaws extended into a beak; pelvic fins very large wing-like; spines absent	Flyingfishes, Halfbeaks, Needlefishes Sauries	Surface, water column	Surface, water column
Killifishes (Orders Cyprinodontiformes)	Small-sized, silvery stripe on sides, pectoral fins high, first dorsal fin with flexible spine, pelvic fin with one spine	California killifish	NA	Surface, water column

Table 3.6-2: Major Taxonomic Groups of Fishes in the Hawaii-Southern California Training and Testing Study Area (continued)

Major Fish Groups			*Occurrence in the Study Area*	
Group Names	***Description***	***Representative Species***	***Open Ocean***	***Coastal Waters ****
Silversides (Order Atheriniformes)	Protrusible upper jaw; fin spines rarely present; single dorsal fin	Grunion, Jacksmelt, Topsmelt	NA	Water column
Opahs and allies (Order Lampriformes	Upper jaw protrusible; pelvic fins forward on body, below or just behind insertion of pectoral fins	Crestfishes, Oarfishes, Opahs, Ribbonfishes, Tapertails, Tube-eyes	Water column, seafloor	NA
Squirrelfishes and allies (Order Beryciformes)	Body usually round, one dorsal fin often set far back, pelvic fins absent, fin spines often present	Bigscales, Fangtooths, Pricklefish, Slimeheads, Squirrelfishes Whalefishes	Water column, seafloor	NA
Dories and allies (Order Zeiformes)	Body deeply compressed, protrusible jaws, spines in dorsal fin, pelvic fin spines sometimes present	Boarfishes, Dories, Oreos, Tinselfishes	Water column, seafloor	NA
Pipefishes (Order Syngnathiformes)	Snout tube-like, mouth small, scales often modified bony plates	Cornetfish, Seahorses, Snipefishes	Water column, seafloor	Seafloor
Sticklebacks (Order Gasterosteiformes)	Mouth small, scales often modified bony plates	Threespine stickleback	Water column, seafloor	Seafloor
Scorpionfishes (Order Scorpaeniformes)	Usually strong spines on head and dorsal fin; cheeks with bony struts, pectoral fins usually rounded	Poachers, Rockfishes, Sculpins Snailfishes	Water column, seafloor	NA

Table 3.6-2: Major Taxonomic Groups of Fishes in the Hawaii-Southern California Training and Testing Study Area (continued)

Major Fish Groups			*Occurrence in the Study Area*	
Group Names	***Description***	***Representative Species***	***Open Ocean***	***Coastal Waters ****
Mullets (Order Mugiliformes)	Streamline body, forked tail, hard angled mouth, large scales	Acute-jawed, Flathead grey, Kanda	NA	Surface, water column, seafloor
Perch-like Fishes and Allies (Order Perciformes)	Deep bodied, to moderately elongate, 1-2 dorsal fins, large mouth and eyes, and throracic pelvic fins	Angelfishes, Cardinal Fishes, Drums, Groupers, Jacks, Remoras, Surfperches	Water column, seafloor	Water column, seafloor
Wrasses and Allies (Order Perciformes)	Compressed body, scales large, well-developed teeth, usually colorful	Hogfishes, Parrotfishes, Wrasses, Damselfishes	NA	Seafloor
Eelpouts and Allies (Order Perciformes)	Eel-like body, long dorsal and anal fins, pelvic fins usually absent	Gunnels, Ocean pout, Pricklebacks, Wolfeels	Seafloor	Seafloor
Stargazers (Order Perciformes)	Body elongated, lower jaw usually projecting beyond upper jaw, pelvic and anal fins with spines	Stargazers	Water column, seafloor	Water column, seafloor
Blennies, Gobies, and Allies (Order Perciformes)	Body eel-like to sculpin-like, pelvic fins reduced or fused	Blackeye and cheekspot goby, mussel blenny	NA	Seafloor
Surgeonfishes (Order Perciformes)	Body deeply compressed laterally, mouth small, scales usually small, pelvic fins with spines	Achilles tang, Surgeonfishes	NA	NA
Tunas and Allies (Order Perciformes)	Large mouth, inlets and keels usually present, pelvic fins often absent or reduced, fast swimmers	Barracudas, Billfishes, Swordfishes, Tunas	Surface, water column	Water column for juvenile barracudas only

Table 3.6-2: Major Taxonomic Groups of Fishes in the Hawaii-Southern California Training and Testing Study Area (continued)

Major Fish Groups			*Occurrence in the Study Area*	
Group Names	***Description***	***Representative Species***	***Open Ocean***	***Coastal Waters ****
Butterfishes (Order Perciformes)	Snout blunt and thick, teeth small, maxilla mostly covered by bone	Ariommatids, Driftfishes, Medusafishes	Surface, water column, seafloor	NA
Flatfishes (Order Pleuronectiformes)	Body flattened; eyes on one side of body	Flounders, Halibuts, Sanddabs, Soles, Tonguefishes	Seafloor	Seafloor
Pufferfishes (Order Tetraodontiformes)	Skin thick or rough sometimes with spines or scaly plates, pelvic fins absent or reduced, small mouth with strong teeth coalesced into biting plate	Boxfishes, Filefishes, Ocean sunfishes, Triggerfishes	Water column	Surface, water column, seafloor

* Coastal Waters include bays, estuaries, and harbors.
Note: NA = not applicable

3.6.2.3.1 Jawless Fishes-Hagfishes (Order Myxiniformes) and Lampreys (Order Petromyzontiformes)

Hagfishes and lamprey are primitive, cartilaginous, vertebrates with very limited external features often associated with fishes, such as fins and scales (Helfman et al., 2009). Both groups inhabit marine water column and soft bottom seafloor habitats in depths greater than 30 m and below 13°C in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems.

Hagfish reproduction and early development has not been observed, and captive breeding has been unsuccessful (Powell et al., 2005). Females lay leathery eggs on the seafloor and when the eggs hatch, they are essentially miniature adults. Hagfishes prey on dying fishes or feed on dead fishes. Some hagfishes have commercial fishery importance as their external "skin" is used for making "eel leather" goods.

Lampreys are anadromous and larvae are buried in the soft bottoms of river backwaters (Moyle & Cech, 2004). Juvenile lamprey filter feed on algae and detritus. Adults are parasitic and use their oral disc mouth to attach to other fishes and feed on their blood (Moyle & Cech, 2004; Nelson et al., 2004). Hagfishes and lampreys have no known predators.

3.6.2.3.2 Ground Sharks (Orders Carcharhiniformes), Mackerel Sharks (Order Lamniformes), Carpet Sharks (Order Orectolobiformes), and Bullhead Sharks (Order Heterodontiformes)

Ground Sharks and allies (bull, dusky, hammerheads, oceanic whitetip, and tiger) are cartilaginous fishes with two dorsal fins, an anal fin, five gill slits, and eyes with nictitating membranes. Reproduction includes internal fertilization with the young born fully developed. These sharks are highly migratory. They are found in the water column and bottom/seafloor habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems and open ocean areas. These sharks are associated with hard and soft bottoms, nearshore and open ocean surface waters, and deep-sea habitats.

Mackerel Sharks and allies (great white, makos, and porbeagle) are cartilaginous fishes with a large first dorsal fin that is high, erect, and angular or somewhat rounded, anal fin with a keel, and a mouth extending behind the eyes. Reproduction includes internal fertilization with young being produced by means of eggs that are hatched within the body of the female. They are found in the water column and bottom/seafloor habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems and open ocean areas. These sharks are associated with nearshore and open ocean surface water habitats. Ground and Mackerel Sharks are efficient predators on large fishes, cephalopods, and marine mammals. Some species are targeted for commercial and recreational purposes.

Carpet Sharks and allies are a diverse group inhabiting coral and rocky reefs in the order Orectolobiformes. This group includes whale sharks, which are the largest shark in the group and are one of three filter feeding sharks. Many of the carpet sharks, such as whale shark, are also highly migratory. Carpet sharks all share certain characteristics, including their mouth being completely in front of the eyes, both dorsal fins without spines, five pairs of gill slits, and an anal fin being present. Nurse sharks are also in this group and are usually yellowish-tan to dark brown, average around 8–9 feet long, and can weigh over 200 pounds. They are nocturnal, scouting the sea bottom for prey such as crustaceans, molluscs, and stingrays. They spend most of the day resting on sandy bottom or in caves or reef crevices. Whale sharks are another member of the carpet sharks group and are the largest shark in the world, growing to a length of over 40 feet.

Bullhead sharks and allies (horn shark) are cartilaginous fishes with two dorsal fins, an anal fin, five gill slits, and eyes without nictitating membranes. Reproduction includes internal fertilization with egg cases laid in crevices. They are found in the bottom/seafloor habitat in the California Current Large Marine Ecosystems and are associated with soft bottoms habitat.

3.6.2.3.3 Frilled and Cow Sharks (Order Hexanchiformes), Dogfish Sharks (Order Squaliformes), and Angel Sharks (Order Squatiniformes)

Frill and cow sharks (sevengill, sixgill) are cartilaginous fishes, generally characterized by lacking traits such as an anal fin and nictitating membrane; they do possess six to seven gill slits, compared to five gill slits found in all other sharks. Reproduction includes internal fertilization with young being produced by means of eggs that are hatched within the body of the female. They are associated with deep-sea habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004).

Dogfish sharks are cartilaginous fishes with two dorsal fins spines and a caudal fin that's divided into two lobes: a larger dorsal lobe and a smaller ventral lobe. Reproduction includes internal fertilization with young emerging from eggs that are hatched within the body of the female. They are associated with soft bottom and deep-sea habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004).

Angel sharks (e.g., Pacific angel shark) are cartilaginous fishes with flat, batoid-like body, two small spineless dorsal fins behind pelvic fins, and anal fin absent. Reproduction includes internal fertilization with young emerging from eggs that are hatched within the body of the female. They are associated with soft bottom habitat in the California Current Large Marine Ecosystem (Froese & Pauly, 2016; Moyle & Cech, 2004).

3.6.2.3.4 Stingrays and Allies (Order Myliobatiformes), Sawfishes (Order Pristiformes), Skates and Guitarfishes (Order Rajiformes), and Electric Rays (Order Torpediniformes)

Stingrays and allies (eagle ray, manta) are cartilaginous fishes, distinguished by flattened bodies, enlarged pectoral fins that are fused to the head and gill slits that are placed on their ventral surfaces. Reproduction includes internal fertilization with the young born fully developed. They are associated with reefs, nearshore open ocean, inland waters, and deep-sea water column habitat in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004).

Skates and guitarfishes are cartilaginous fishes, distinguished by flattened bodies, two reduced dorsal fins, and a reduced caudal fin. Reproduction includes internal fertilization and deposition of egg sacks. They are associated with soft bottom habitat in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004).

Electric rays are cartilaginous fishes, distinguished by flattened bodies, two well-developed dorsal fins and caudal fin. Two large kidney shaped organs in a disc on either side of the electric ray's head distinguish it from others, as these organs are able to produce strong electric shock at will (Madl & Yip, 2000). Reproduction includes internal fertilization with young being produced by means of eggs that are hatched within the body of the female. Only one species, the Pacific electric ray (*Torpedo californica*), has been recorded in the Study Area.

3.6.2.3.5 Ratfishes (Order Chimaeriformes)

Ratfishes (chimera, rabbitfish, and ratfish) are cartilaginous fishes, with smooth skin largely covered by placoid scales, and their color can range from black to brownish gray. Reproduction includes internal fertilization and deposition of egg capsules. Fishes in this group are associated with soft bottom and deep-sea habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems (Froese & Pauly, 2016).

3.6.2.3.6 Herrings (Order Clupeiformes)

Herring and allies (anchovies, herrings, sardines, and shad) are bony fishes with a silvery body with the lateral line and fin spines absent, and usually scutes along ventral profile. They are found only in the marine environment in the water column and in seafloor habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems. Herring, menhaden, sardine, and anchovy species are well-known as valuable targets of commercial fisheries. Herring account for a large portion of the total worldwide fish catch (Food and Agriculture Organization of the United Nations, 2005, 2009). Herrings and allies are broadcast spawners. They are known to form schools to help conserve energy and minimize predation (Brehmer et al., 2007), which may facilitate some level of communication during predator avoidance (Marras et al., 2012). They feed on decaying organic matter and plankton while swimming in the water column (Moyle & Cech, 2004). Herring and allies support marine food webs as a forage fish and preyed upon by fish, birds, and marine mammals.

3.6.2.3.7 Tarpons (Orders Elopiformes and Albuliformes)

Tarpons and allies (bonefishes, halosaurs, ladyfish, and machete) are bony fishes with the body encased in silvery scales, a large mouth, a single dorsal fin (most), and a somewhat tapered tail with fin spines absent. They are associated with riverine, estuarine and marine environments on the surface, water column, and seafloor/bottom habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems. Tarpon and allies are important game species but are not considered edible. Tarpons and allies are broadcast spawners. Fertilized eggs float in the water column until hatching into a leptocephalous larva (ribbon-like, with no resemblance to the adult). During the change from larvae to juvenile, the body shrinks in length. Juveniles prey upon plankton and marine invertebrates, while adults feed on mid-water fishes. Tarpon and allies are nocturnal ambush predators (Wainwright & Richard, 1995) who prey on bottom-dwelling invertebrates and small fishes. Tarpons and allies are preyed upon by larger fishes, birds, and marine mammals.

3.6.2.3.8 Eels (Anguilliforms, Notacanthiformes, and Saccopharyngiformes)

Eels (conger, cutthroat, duckbill, false moray, morays, sawtooth, short-tailed, spiny, gulpers, and pelican eels) are bony fishes with a very elongate body, usually scaleless with pelvic fins, and without fin spines. They are associated with riverine, estuarine and marine environments in the water column, and seafloor/bottom habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems. Eels and allies have little fishery importance. Some species are broadcast spawners, and fertilized eggs float in the water column until hatching into a leptocephalous larva. Juveniles prey upon plankton and marine invertebrates, while adults feed on small fishes. Depending on the species and its habitat, eels can be diurnal or nocturnal ambush predators and prey on bottom-dwelling invertebrates and small fishes. Eels are preyed upon mostly by larger fishes.

3.6.2.3.9 Argentines and Allies (Order Argentiniformes)

Argentines and allies (argentines, barreleyes, deep-sea smelts, slickheads, and tubeshoulders) are bony fishes with typically silvery, elongate bodies, adipose fin and extremely large mouths sometimes present, and pelvic fins and spines sometimes absent. They are found only in the marine environment in the water column, and seafloor habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems. Argentines and allies have little fishery importance. Argentines and allies vary in their reproduction strategy. Some deep-sea species are capable of bioluminescence and release scents that may help to attract mates. Argentines are broadcast spawners and fertilized eggs float in the water column until hatching. Argentines and allies likely have few predators, but may be preyed upon by larger fishes.

3.6.2.3.10 Bristlemouths (Order Stomiiformes) and Allies

Bristlemouths and allies (dragonfishes, fangjaws, hatchfishes, and lightfishes) are bony fishes with photophores and adipose fin present and chin barbels sometimes present. Bristlemouths and hatchetfishes are small in size and the most abundant fishes in many parts of the world’s oceans. They are capable of eating large and small prey items and are known to engage in prey-related vertical migration patterns. Other species in this order are largely piscivorous (Moyle & Cech, 2004).

3.6.2.3.11 Greeneyes and Allies (Order Aulopiformes)

Greeneyes and allies (barracudinas, daggertooth, lizardfishes, pearleyes, and waryfishes) are bony fishes with an upper protrusible jaw, an adipose fin and forked tail usually present with fin spines absent. Most greeneyes and allies are small (less than 50 cm) predators capable of devouring a wide range of species, including other fishes nearly their same size and pelagic invertebrates. Fishes in this order are preyed upon by salmon, tunas, and swordfishes. Reproduction is usually external, and includes the ability to change sex (Froese & Pauly, 2016).

3.6.2.3.12 Lanternfishes and Allies (Order Myctophiformes)

Lanternfishes and allies (headlight, lampfishes, and lancetfishes) are bony fishes that are usually small-sized, with an adipose fin, forked tail and photophores usually present. Lanternfishes can occur closer to the surface at night (10-100 m) and deeper during the day (300 to 1200 m) (Froese & Pauly, 2016), where they may become prey for marine mammals. These fishes often are an important part of the deep scattering layer (Moyle & Cech, 2004). Lanternfishes prey upon copepods and krill (Tyler & Pearcy, 1975).

3.6.2.3.13 Hakes and Allies (Order Gadiformes)

Hakes and allies (cods, codlings, grenadiers, and whiptails) are bony fishes with long dorsal and anal fins, no true spines in fins, although spinous rays present in dorsal fin of most species, and chin barbels are often present. Hakes and allies account for approximately half of the global commercial landings (Food and Agriculture Organization of the United Nations, 2005). Prey items for fishes in this group include small crustaceans during juvenile phases and larger crustaceans, squid and fishes as adults. Predators include striped bass, sharks, and cetaceans (Froese & Pauly, 2016).

3.6.2.3.14 Brotulas and Allies (Order Ophidiiformes)

Brotulas and allies (cusk-eels) are bony fishes with pelvic absent or far forward and filamentous, dorsal and anal fins joined to caudal fin, and spines absent. These fishes exhibit a variety of reproductive strategies including external fertilization and giving live birth. Prey items for fishes in this group include small crustaceans during juvenile phases and larger crustaceans, squid and fishes as adults. Predators include striped bass, sharks, and cetaceans (Froese & Pauly, 2016).

3.6.2.3.15 Toadfishes and Allies (Order Batrachoidiformes)

Toadfishes and allies (midshipman) are bony fishes with compressed bodies, large, depressed head and mouth usually with tentacles, and two dorsal fins with the first with spines. These fishes are known to build nests (Moyle & Cech, 2004).

3.6.2.3.16 Anglerfishes and Allies (Order Lophiiformes)

Anglerfishes and allies (footballfishes, frogfishes, goosefishes, and sea devils) are bony fishes with globulose bodies, a spine on the first dorsal fin and the pelvic fins usually absent. Anglerfish attract potential prey using their first dorsal fin (illicium) as a lure (Yasugi & Hori, 2016). Fishes in these orders are found occasionally on the surface, but most frequently in the water column and seafloor habitats. Additional adaptations include large mouths, sharp teeth, and sensitive lateral line [sensory] systems (Haedrich, 1996; Koslow, 1996; Marshall, 1996; Rex & Etter, 1998; Warrant & Locket, 2004). These fishes are mostly generalist feeders. Reproduction is not well studied, but sexes are separate and some exhibit parasitism (Moyle & Cech, 2004). Fishes in this group generally have no fishery importance.

3.6.2.3.17 Flyingfishes (Order Beloniformes)

Flyingfishes (halfbeaks, needlefishes, and sauries) are bony fishes with jaws extended into a beak; pelvic fins very large wing-like; spines absent. These fishes are associated with reefs, submerged aquatic vegetation, and open ocean habitat in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems and open ocean areas (Froese & Pauly, 2016).

3.6.2.3.18 Killifish (Order Cyprinodontiformes)

Killifishes such as the California killifish (*Fundulus parvipinnis*) is bony fish with a protrusible upper jaw, fin spines rarely present, and a single dorsal fin. Killifishes are found in the water column of rivers and estuaries in the California Current Large Marine Ecosystem.

3.6.2.3.19 Silversides (Order Atheriniformes)

Silversides (grunion, jacksmelt, and topsmelt) are bony fishes with a silvery stripe on their sides, high pectoral fins, a dorsal fin, and a pelvic fin with a spine. These fishes are found on the surface and in the water column in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems.

3.6.2.3.20 Opahs and Allies (Order Lampriformes)

Opahs and allies (crestfishes, oarfishes, ribbonfishes, tapertails, and tube-eyes) are bony fishes with an upper protrusible jaw, and pelvic fins located forward on body, below, or just behind insertion of pectoral fins. Toadfishes (midshipman) have compressed bodies; large, depressed head and mouth usually with tentacles; and two dorsal fins, the first with spines. Fishes in this group exhibit a variety of reproductive strategies including external fertilization and parasitism. Prey items for fishes in this group include crustaceans, squid, and fishes. These fishes are found in the water column and seafloor habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems and open ocean areas.

3.6.2.3.21 Squirrelfishes and allies (Order Beryciformes)

Squirrelfishes and allies (bigscales, fangtooths, pricklefishes, slimeheads, and whalefishes) are bony fishes with round bodies and one dorsal fin often set far back, with pelvic fins absent and fin spines often present. Squirrelfishes (family Holocentridae) are the largest and most widely distributed family in the order, with over 60 species found throughout tropical and subtropical marine habitats (Moyle & Cech, 2004). Most species in this group occupy shallow nearshore reef and rocky areas where they hide during the day and come out at night to feed on zooplankton in the water column.

3.6.2.3.22 Dories and Allies (Order Zeitformes)

Dories and allies (boarfishes, oreos, and tinselfishes) are bony fishes that have deeply compressed bodies, protrusible jaws, spines in dorsal fin, and pelvic fin spines sometimes present. There are three species reported in the Study Area (Froese & Pauly, 2016). These fishes are only found in marine habitats, and most are deep-sea species. Fishes in this order typically have large heads with distensible jaws that allow them to capture larger-sized prey, including fishes and crustaceans.

3.6.2.3.23 Pipefishes and Allies (Orders Syngnathiformes)

Pipefishes and allies (cornetfish, seahorses, and snipefishes) are bony fishes that exhibit unique body shapes with a tube-like snout, small mouth, and scales that are often modified bony plates. These fishes are associated with hard and soft bottom, submerged aquatic vegetation, reefs, and deep-sea habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems (Froese & Pauly, 2016; Paxton & Eshmeyer, 1998). Some pipefishes and allies exhibit a high level of parental care by brooding pouches (male seahorses), which results in relatively few young being produced (Helfman et al., 2009).

Most fishes in this group are diurnal ambush predators and prey on zooplankton, marine invertebrates, and small fishes. Pipefishes and allies are preyed upon by larger fishes and birds.

3.6.2.3.24 Sticklebacks (Order Gasterosteiformes)

Sticklebacks are small fishes comprised of only seven species that live in freshwater, saltwater, or brackish water (Helfman et al., 2009; Moyle & Cech, 2004). Species in this group are easily recognized by the presence of three to 16 isolated spines on their back in front of the dorsal fin, large eyes, and small upturned mouths. Most species in this group possess a row of bony plates on each side. Some sticklebacks display parental care through nest building. Fishes in this group are found in littoral marine waters and freshwater habitats in the Study Area.

3.6.2.3.25 Scorpionfishes (Order Scorpaeniformes)

Scorpionfishes and allies (poachers, rockfishes, snailfishes, and sculpins) are bony fishes with usually strong spines on head and dorsal fin, cheeks with bony struts, and rounded pectoral fins. These fishes are associated with hard and soft bottom, reefs, and deep-sea habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems and open ocean areas (Froese & Pauly, 2016; Paxton & Eshmeyer, 1998). Some scorpionfishes have commercial and recreation fishery importance (Moyle & Cech, 2004). Reproduction methods vary widely between species and include external fertilization and egg deposition (sculpins) and internal fertilization and bearing live young (rockfishes). Most fishes in this group are diurnal ambush predators and prey on bottom-dwelling invertebrates and small fishes. Scorpionfishes are allies are preyed upon by larger fishes, birds, and marine mammals.

3.6.2.3.26 Mullets (Order Mugiliformes)

Mullets (blue spot, flathead grey, kanga, striped) are bony fishes with a streamline body, forked tail, hard angled mouth, large scales, high pectoral fins, and pelvic fins with one spine. Striped mullet is an important commercial fishery (Froese & Pauly, 2016). These fishes are associated with soft bottom, reefs, and nearshore open ocean habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004). Mullet are catadromous; they spawn in saltwater but spend most of their lives in freshwater environments. Mullet farming is also an ancient Hawaiian tradition that pre-dates European contact with the islands (Costa-Pierce, 2012). Fishponds in ancient Hawaii were developed in upland areas to cultivate taro and simultaneously grow a limited range of euryhaline and freshwater fish, such as mullet.

3.6.2.3.27 Order Perciformes

Perciforms are the largest order of vertebrates, with over 7,800 species. They are extremely diverse, but most species are adapted for life as predators in the shallow or surface waters of the ocean. Some of the characteristics include fin spines present, dorsal fins either double or made up of two distinct parts with the lead spiny, adipose fin absent, pelvic fins thoracic or jugular in position or absent, pectoral fins on side of body, ctenoid scales, and closed swim bladder. Nearly half of all species belong to four families: gobies, wrasses, seabasses, or blennies(Moyle & Cech, 2004). Fish groupings in this section generally follow the classification in Nelson (2016).

3.6.2.3.27.1 Perches and Allies

Perches and allies (angelfishes, cardinal fishes, damselfishes, drums, grunts, jacks, remoras, sea basses, snappers, striped bass, and surfperches) are bony fishes with deep to moderately elongate bodies, one to two dorsal fins, with large mouth and eyes and thoracic pelvic fins. These fishes are associated with hard and soft bottom, reefs, submerged aquatic vegetation, open ocean, and deep-sea habitats in the

California Current and Insular Pacific-Hawaiian Large Marine Ecosystems and open ocean areas (Froese & Pauly, 2016; Moyle & Cech, 2004).

3.6.2.3.27.2 Wrasses and Allies

Wrasses and allies (hogfishes, parrotfishes, wrasses, and damselfishes) are bony fishes with a compressed body, large scales, well-developed teeth, and usually colorful coloring. Some wrasses and allies have recreational fishery and aquarium trade importance. Most of these fishes are associated with depths less than 30 meters hard and soft bottom and reef habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004). Wrasses and allies can change sex, usually female-to-male, and exhibit broadcast spawning; the fertilized eggs float in the water column or attach to substrate until hatching into larvae. Most are diurnal opportunistic predators (Wainwright & Richard, 1995). Prey items include zooplankton, invertebrates, and small fishes. Predators of wrasses and allies include larger fishes and marine mammals.

3.6.2.3.27.3 Eelpouts and Allies

Eelpouts and allies (gunnels, ocean pout, pricklebacks, and wolfeels) are bony fishes with an eel-like body, long dorsal and anal fins, and pelvic fins usually absent. These fishes are associated with soft bottom and deep-sea habitats in the California Current Large Marine Ecosystem (Froese & Pauly, 2016; Moyle & Cech, 2004). Eelpouts have been found to occur near deep-sea vents in the Atlantic Ocean's Mid-Atlantic Ridge (National Geographic, 2016) and in deep water areas off Oahu and the Northern Hawaiian Islands (Yeh, 2008).

3.6.2.3.27.4 Stargazers

Stargazers are bony fishes with an elongated body and eyes on top of their head and big oblique mouths and are associated with soft bottom and deep-sea habitats in the California Current Large Marine Ecosystem (Froese & Pauly, 2016). This group of fishes ambush their prey from the sand.

3.6.2.3.27.5 Blennies, Gobies, and Allies

Blennies, gobies, and allies (blackeye goby, cheekspot goby, mussel blenny) are bony fishes with an eel-like to sculpin-like body, and pelvic fins reduced or fused. They are associated with hard and soft bottoms, reefs, and deep-sea habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems (Froese & Pauly, 2016).

3.6.2.3.27.6 Surgeonfishes

Surgeonfish (blue tang, moorish idol) are bony fishes with bodies that are deeply compressed laterally, small mouth, small scales, and pelvic fins with spines. They are associated with reef habitats in the Insular Pacific-Hawaiian Large Marine Ecosystem (Froese & Pauly, 2016). These fishes scrape algae from coral reefs with small, elongated mouths. These grazers provide an important function to the reef system by controlling the growth of algae on the reef (Goatley & Bellwood, 2009).

3.6.2.3.27.7 Tunas and Allies

The tuna and allies (barracudas, billfishes, swordfishes, and tunas) have a large mouth, keels usually present, pelvic fins often absent or reduced, and are fast swimmers. These fishes are associated with reefs, nearshore and offshore open ocean habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004). Most species have commercial and recreational importance. Tuna and allies are voracious open ocean predators (Estrada et al., 2003). They exhibit broadcast spawning and fertilized eggs float in the water column until hatching into larvae.

Many feed nocturnally (Goatley & Bellwood, 2009) and in low-light conditions of twilight (Rickel & Genin, 2005). Many species in this group make large-scale migrations that allow for feeding in highly productive areas, which vary by season (Pitcher, 1995). Prey items include zooplankton for larvae and juvenile stages, while fishes and squid are consumed by subadults and adults. Predators of tuna and allies include other tuna species, billfishes, toothed whales, and some open ocean shark species. The Pacific bluefin tuna is a candidate species for listing under ESA, as presented in Table 3.6-1.

3.6.2.3.27.8 Butterfishes

Butterfishes (ariommas, driftfishes, and medusafishes) are bony fishes with a blunt and thick snout, teeth small, and a maxilla mostly covered by bone. They are associated with soft bottom and deep-sea habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems (Froese & Pauly, 2016). Butterfishes form large schools over the continental shelf, except during winter months when it may descend to deeper waters. Juveniles are associated with jellies and floating vegetation. Adults feed mainly on jellies, squids, and crustaceans. Some species of butterfishes are also commercially harvested (Froese & Pauly, 2016).

3.6.2.3.28 Flatfishes (Order Pleuronectiformes)

Flatfish (flounders, halibut, sand dabs, soles, and tonguefish) are bony fishes with a flattened body and eyes on one side of body. These fishes occur on soft bottom habitat in inland waters, as well as in deep-sea habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems, and are an important part of commercial fisheries in the Study Area. The California halibut (*Paralichthys californicus*) is a representative of this group and is a recreationally fished species. Flatfishes are broadcast spawners. They are ambush predators, and prey on other fishes and bottom-dwelling invertebrates. Some species in this group have been affected by overfishing (Drazen & Seibel, 2007; Froese & Pauly, 2010).

3.6.2.3.29 Pufferfishes (Order Tetradontiformes)

Pufferfishes (boxfishes, filefishes, ocean sunfishes and triggerfishes) are bony fishes with thick or rough skin, sometimes with spines or scaly plates, pelvic fins absent or reduced, and a small mouth with strong teeth coalesced into a biting plate. They are associated with hard and soft bottom, reef, submerged aquatic vegetation, nearshore and offshore open-ocean, and deep-sea habitats in the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems. Pufferfishes are broadcast spawners. Predators vary by species, but due to spiny and rough exterior of this group, it is likely few are successful. Prey vary by species, but includes jellies, crustaceans, detritus, molluscs, and other bottom dwelling marine invertebrates (Froese & Pauly, 2016).

3.6.3 Environmental Consequences

This section evaluates how, and to what degree, the activities described in Chapter 2 (Description of Proposed Action and Alternatives) potentially impact fishes known to occur within the Study Area. Tables 2.6-1 through 2.6-5 present the proposed typical training and testing activity locations for each alternative (including number of events). General characteristics of all U.S. Department of the Navy (Navy) stressors were introduced in Section 3.0.3.3 (Identifying Stressors for Analysis), and living resources' general susceptibilities to stressors were introduced in Section 3.0.3.6 (Biological Resource Methods). The stressors vary in intensity, frequency, duration, and location within the Study Area. The stressors analyzed for fishes are

- **Acoustic** (sonar and other transducers; air guns; pile driving; vessel noise; aircraft noise; and weapons noise)
- **Explosives** (in-air explosions and in-water explosions)
- **Energy** (in-water electromagnetic devices and high-energy lasers)
- **Physical disturbance and strikes** (vessels and in-water devices, military expended materials, and seafloor devices)
- **Entanglement** (wires and cables, decelerators/parachutes, and biodegradable polymers)
- **Ingestion** (military expended materials – munitions and military expended materials – other than munitions)
- **Secondary stressors** (impacts on habitat and prey availability)

The analysis focuses on the fish groups and ESA-listed fish species discussed in Section 3.6.2 (Affected Environment). The analysis includes consideration of the mitigation that the Navy will implement to avoid potential impacts on fishes from explosives and physical disturbance and strike stressors. Mitigation for fishes was coordinated with NMFS through the consultation processes.

3.6.3.1 Acoustic Stressors

The following section analyzes potential impacts on fishes from proposed activities that involve acoustic stressors (i.e., sonar and other transducers; air guns; pile driving; vessel noise; aircraft noise; and weapons noise). It follows the outline and methodology for assessing potential impacts put forth in Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities).

3.6.3.1.1 Background

Effects of human-generated sound on fishes have been examined in numerous publications (Hastings & Popper, 2005; Hawkins et al., 2015; Mann, 2016; National Research Council, 1994, 2003; Neenan et al., 2016; Popper et al., 2004; Popper, 2003, 2008; Popper & Hastings, 2009a; Popper et al., 2014; Popper et al., 2016). The potential impacts from Navy activities are based on the analysis of available literature related to each type of effect. In addition, a Working Group organized under the American National Standards Institute-Accredited Standards Committee S3, Subcommittee 1, Animal Bioacoustics, developed sound exposure guidelines for fish and sea turtles (Popper et al., 2014), hereafter referred to as the *ANSI Sound Exposure Guideline* technical report. Where applicable, thresholds and relative risk factors presented in the *ANSI Sound Exposure Guideline* technical report were used to assist in the analysis of effects to fishes from Navy activities.

There are limited studies of fish responses to aircraft and weapons noise. For the purposes of this analysis, studies of the effects from sonar or vessel noise are used to inform fish responses to other continuous sources such as aircraft noise. Studies of the effects from impulsive sources (i.e., air guns and pile driving) are used to inform fish responses to other impulsive sources such as weapons noise. Where data from sonar and vessel noise exposures are limited, other continuous sounds such as white noise is used as a proxy to better understand potential reactions from fish. The following section discusses available information for non-explosive acoustic sources. Information on potential impacts from explosive sources is described under Section 3.6.3.2 (Explosive Stressors) where it differs from other impulsive sources described below.

3.6.3.1.1.1 Injury

Injury refers to the direct effects on the tissues or organs of a fish. Research on injury in fish caused by exposure to high-intensity or long-duration sound from air guns, impact pile driving and some sonars is discussed below. Moderate- to low-level noise from vessels, aircraft, and weapons use is described in

Section 3.0.3.3.1 (Acoustic Stressors) and lacks the amplitude and energy to cause any direct injury. Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) provides additional information on injury and the framework used to analyze this potential impact.

Injury due to Impulsive Sound Sources

Impulsive sounds, such as those produced by seismic air guns and impact pile driving, may cause injury or mortality in fishes. Mortality and potential damage to the cells of the lateral line have been observed in fish larvae, fry, and embryos after exposure to single shots from a seismic air gun within close proximity to the sound source (0.1 to 6 m) (Booman et al., 1996; Cox et al., 2012). However, exposure of adult fish to a single shot from an air gun array (four air guns) within similar ranges (6 m), has not resulted in any signs of mortality within seven days after exposure (Popper et al., 2016). Although injuries occurred in adult fishes, they were similar to injuries seen in control subjects (i.e., fishes that were not exposed to the air gun) so there is little evidence that the air gun exposure solely contributed to the observed effects.

Injuries, such as ruptured swim bladders, hematomas, and hemorrhaging of other gas-filled organs, have been reported in fish exposed to a large number of simulated impact pile driving strikes with cumulative sound exposure levels up to 219 decibels referenced to 1 micropascal squared seconds (dB re 1 µPa^2-s) under highly controlled settings where fish were unable to avoid the source (Casper et al., 2012b; Casper et al., 2013a; Casper et al., 2013b; Halvorsen et al., 2011; Halvorsen et al., 2012a; Halvorsen et al., 2012b). However, it is important to note that these studies exposed fish to 900 or more strikes as the studies goal was largely to evaluate the equal energy hypothesis, which suggests that the effects of a large single pulse of energy is equivalent to the effects of energy received from many smaller pulses (as discussed in Smith & Gilley, 2008). Halvorsen et al. (2011) and Casper et al. (2017) found that the equal energy hypothesis does not apply to effects of pile driving; rather, metrics relevant to injury could include, but not be limited to, cumulative sound exposure level, single strike sound exposure level, and number of strikes (Halvorsen et al., 2011). Furthermore, Casper et al. (2017) found the amount of energy in each pile strike and the number of strikes determines the severity of the exposure and the injuries that may be observed. For example, hybrid striped bass (white bass *Morone chrysops* x striped bass *Morone saxaltilis*) exposed to fewer strikes with higher single strike sound exposure values resulted in a higher number of, and more severe, injuries than bass exposed to an equivalent cumulative sound exposure level that contained more strikes with lower single strike sound exposure values. This is important to consider when comparing data from pile driving studies to potential effects from other impulsive sources (such as an explosion). Although single strike peak sound pressure levels were measured during these experiments (at average levels of 207 dB re 1 µPa), the injuries were only observed during exposures to multiple strikes; therefore, it is anticipated that a peak value much higher than those measured in these studies would be required to lead to injury.

These studies included species both with and without swim bladders. The majority of fish that exhibited injuries were those with swim bladders. Lake sturgeon (*Acipenser fulyescens*), a physostomous fish, was found to be less susceptible to injury from impulsive sources than Nile tilapia (*Oreochromis niloticus*) or hybrid striped bass, physoclistous fishes (Casper et al., 2017; Halvorsen et al., 2012a). As reported by Halvorsen et al. (2012a), the difference in results is likely due to the type of swim bladder in each fish. Physostomous fishes have an open duct connecting the swim bladder to their esophagus and may be able to quickly adjust the amount of gas in their body by gulping or releasing air. Physoclistous fishes do not have this duct; instead, gas pressure in the swim bladder is regulated by special tissues or glands. There were no mortalities reported during these experiments, and in the studies where recovery was observed, the majority of exposure related injuries healed within a few days in a laboratory setting. In many of these controlled studies, neutral buoyancy was determined in the fishes prior to exposure to the simulated pile driving. However, fishes with similar physiology to those described in these studies that are exposed to actual pile driving activities may show varying levels of injury depending on their state of buoyancy.

Debusschere et al. (2014) largely confirmed the results discussed in the paragraph above with caged juvenile European sea bass (*Dicentrarchus labrax*) exposed to actual pile driving operations. No differences in mortality were found between control and experimental groups at similar levels tested in the experiments described in the paragraph above (sound exposure levels up to 215–222 dB re 1 μPa^2-s) and many of the same types of injuries occurred. Fishes with injuries from impulsive sources such as these may not survive in the wild due to harsher conditions and risk of predation.

Other potential effects from exposure to impulsive sound sources include potential bubble formation and neurotrauma. It is speculated that high sound pressure levels may also cause bubbles to form from micronuclei in the blood stream or other tissues of animals, possibly causing embolism damage (Hastings & Popper, 2005). Fishes have small capillaries where these bubbles could be caught and lead to the rupturing of the capillaries and internal bleeding. It has also been speculated that this phenomena could take place in the eyes of fish due to potentially high gas saturation within the eye tissues (Popper & Hastings, 2009a). Additional research is necessary to verify if these speculations apply to exposures to non-impulsive sources such as sonars. These phenomena have not been well studied in fishes and are difficult to recreate under real-world conditions.

As summarized in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), exposure to high intensity and long duration impact pile driving or air gun shots did not cause mortality, and fishes typically recovered from injuries in controlled laboratory settings. Species tested to date can be used as viable surrogates for investigating injury in other species exposed to similar sources (Popper et al., 2014).

Injury due to Sonar and Other Transducers

Non-impulsive sound sources (e.g., sonar, acoustic modems, and sonobuoys) have not been known to cause direct injury or mortality to fish under conditions that would be found in the wild (Halvorsen et al., 2012a; Kane et al., 2010; Popper et al., 2007). Potential direct injuries (e.g., barotrauma, hemorrhage or rupture of organs or tissue) from non-impulsive sound sources, such as sonar, are unlikely because of slow rise times,[1] lack of a strong shock wave such as that associated with an explosive, and relatively low peak pressures. General categories and characteristics of Navy sonar systems are described in Section 3.0.3.3.1.1 (Sonar and Other Transducers).

The effects of mid-frequency sonar-like signals (1.5–6.5 kHz) on larval and juvenile Atlantic herring (*Clupea harengus*), Atlantic cod (*Gadus morhura*), saithe (*Pollachius virens*), and spotted wolffish (*Anarhichas minor*) were examined by Jørgensen et al. (2005). Researchers investigated potential effects on survival, development, and behavior in this study. Among fish kept in tanks and observed for one to four weeks after sound exposure, no significant differences in mortality or growth-related parameters between exposed and unexposed groups were observed. Examination of organs and tissues from

[1] Rise time: the amount of time for a signal to change from static pressure (the ambient pressure without the added sound) to high pressure. Rise times for non-impulsive sound typically have relatively gradual increases in pressure where impulsive sound has near instantaneous rise to a high peak pressure. For more detail, see Appendix D (Acoustic and Explosive Concepts).

selected herring experiments did not reveal obvious differences between unexposed and exposed groups. However, two (out of 42) of the herring groups exposed to sound pressure levels of 189 dB re 1 μPa and 179 dB re 1 μPa had a post-exposure mortality of 19 and 30 percent, respectively. It is not clear if this increased mortality was due to the received level or to other unknown factors, such as exposure to the resonance frequency of the swim bladder. Jørgensen et al. (2005) estimated a resonant frequency of 1.8 kHz for herring and saithe ranging in size from 6.3 to 7.0 cm, respectively, which lies within the range of frequencies used during sound exposures and therefore may explain some of the noted mortalities.

Individual juvenile fish with a swim bladder resonance in the frequency range of the operational sonars may be more susceptible to injury or mortality. Past research has demonstrated that fish species, size and depth influences resonant frequency (Løvik & Hovem, 1979; McCartney & Stubbs, 1971). At resonance, the swim bladder, which can amplify vibrations that reach the fishes hearing organs, may absorb much of the acoustic energy in the impinging sound wave. It is suspected that the resulting oscillations may cause mortality, harm the auditory organs or the swim bladder (Jørgensen et al., 2005; Kvadsheim & Sevaldsen, 2005). However, damage to the swim bladder and to tissues surrounding the swim bladder was not observed in fishes exposed to sonar at their presumed swim bladder resonant frequency (Jørgensen et al., 2005). The physiological effect of sonars on adult fish is expected to be less than for juvenile fish because adult fish are in a more robust stage of development, the swim bladder resonant frequencies would be lower than that of mid-frequency active sonar, and adult fish have more ability to move from an unpleasant stimulus (Kvadsheim & Sevaldsen, 2005). Lower frequencies (i.e., generally below 1 kHz) are expected to produce swim bladder resonance in adult fishes from about 10–100 cm (McCartney & Stubbs, 1971). Fish, especially larval and small juveniles, are more susceptible to injury from swim bladder resonance when exposed to continuous signals within the resonant frequency range.

Hastings (1995) found "acoustic stunning" (loss of consciousness) in blue gouramis (*Trichogaster trichopterus*), a freshwater species, following an 8-minute continuous exposure to a 150 Hz pure tone with a sound pressure level of 198 dB re 1 μPa. This species of fish has an air bubble in the mouth cavity directly adjacent to the animal's braincase that may have caused this injury. Hastings (1991; 1995) also found that goldfish (*Carassius auratus*), also a freshwater species, exposed to a 250 Hz continuous wave sound with peak pressures of 204 dB re 1 μPa for two hours, and blue gourami exposed to a 150 Hz continuous wave sound at a sound pressure level of 198 dB re 1 μPa for 0.5 hours did not survive. These studies are examples of the highest known levels tested on fish and for relatively long durations. Stunning and mortality due to exposure to non-impulsive sound exposure has not been observed in other studies.

Three freshwater species of fish, the rainbow trout (*Oncorhynchus mykiss*, a species known to occur within the Study Area), channel catfish (*Ictalurus punctatus*), and the hybrid sunfish (*Lepomis* sp.), were exposed to both low- and mid-frequency sonar (Kane et al., 2010; Popper et al., 2007). Low-frequency exposures with received sound pressure levels of 193 dB re 1 μPa occurred for either 324 or 648 seconds. Mid-frequency exposures with received sound pressure levels of 210 dB re 1 μPa occurred for 15 seconds. No fish mortality resulted from either experiment, and during necropsy after test exposures, both studies found that none of the subjects showed signs of tissue damage related to exposure (Kane et al., 2010; Popper et al., 2007).

As summarized in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), although fish have been injured and killed due to intense, long-duration non-impulsive sound exposures, fish exposed under more realistic conditions have shown no signs of injury. Those species tested to date can be used as viable surrogates for estimating injury in other species exposed to similar sources.

3.6.3.1.1.2 Hearing Loss

Researchers have examined the effects on hearing in fishes from sonar-like signals, tones, and different non-impulsive noise sources; however, studies from impulsive sources are limited to air gun and impact pile driving exposures. Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) provides additional information on hearing loss and the framework used to analyze this potential impact.

Exposure to high-intensity sound can cause hearing loss, also known as a noise-induced threshold shift, or simply a threshold shift (Miller, 1974). A temporary threshold shift (TTS) is a temporary, recoverable loss of hearing sensitivity. A TTS may last several minutes to several weeks, and the duration may be related to the intensity of the sound source and the duration of the sound (including multiple exposures). A permanent threshold shift (PTS) is non-recoverable, results from the destruction of tissues within the auditory system, permanent loss of hair cells, or damage to auditory nerve fibers (Liberman, 2016), and can occur over a small range of frequencies related to the sound exposure. However, the sensory hair cells of the inner ear in fishes are regularly replaced over time when they are damaged, unlike in mammals where sensory hair cells loss is permanent (Lombarte et al., 1993; Popper et al., 2014; Smith et al., 2006). As a consequence, PTS has not been known to occur in fishes, and any hearing loss in fish may be as temporary as the timeframe required to repair or replace the sensory cells that were damaged or destroyed (Popper et al., 2005; Popper et al., 2014; Smith et al., 2006). Although available data for some terrestrial mammals have shown signs of nerve damage after severe threshold shifts (e.g., Kujawa & Liberman, 2009; Lin et al., 2011), it is not known if damage to auditory nerve fibers could also occur in fishes, and if so, whether fibers would recover during this process. As with TTS, the animal does not become deaf but requires a louder sound stimulus, relative to the amount of PTS, to detect a sound within the affected frequencies.

<u>**Hearing Loss due to Impulsive Sound Sources**</u>

Popper et al. (2005) examined the effects of a seismic air gun array on a fish with a swim bladder that is involved in hearing, the lake chub (*Couesius plumbeus*), and two species that have a swim bladder that is not involved in hearing, the northern pike (*Esox lucius*) and the broad whitefish (*Coregonus nasus*), a salmonid. In this study, the lowest received cumulative sound exposure level (5 shots with a mean sound pressure level of 177 dB re 1 μPa) at which effects were noted was 186 dB re 1 μPa^2-s. The results showed temporary hearing loss for both lake chub and northern pike to both 5 and 20 air gun shots, but not for the broad whitefish. Hearing loss was approximately 20 to 25 dB at some frequencies for both species, and full recovery of hearing took place within 18 hours after sound exposure. Examination of the sensory surfaces of the ears after allotted recovery times (one hour for 5 shot exposures, and up to 18 hours for 20 shot exposures) showed no damage to sensory hair cells in any of the fish from these exposures (Song et al., 2008).

McCauley et al. (2003) and McCauley and Kent (2012) showed loss of a small percent of sensory hair cells in the inner ear of caged fish exposed to a towed air gun array simulating a passing seismic vessel. Pink snapper (*Pargus auratus*), a species that has a swim bladder that is not involved in hearing, were exposed to multiple air gun shots for up to 1.5 hours (McCauley et al., 2003) where the maximum received sound exposure levels exceeded 180 dB re 1 μPa^2-s. The loss of sensory hair cells continued to increase for up to at least 58 days post exposure to 2.7 percent of the total cells. Gold band snapper

(*Pristipomoides multidens*) and sea perch (*Lutjanis kasmira*), both fishes with a swim bladder involved in hearing, were also exposed to a towed air gun array simulating a passing seismic vessel (McCauley & Kent, 2012). Although received levels for these exposures have not been published, hair cell damage increased as the range of the exposure (i.e., range to the source) decreased. Again, the amount of damage was considered small in each case (McCauley & Kent, 2012). It is not known if this hair cell loss would result in hearing loss since fish have tens or even hundreds of thousands of sensory hair cells in the inner ear and only a small portion were affected by the sound (Lombarte & Popper, 1994; Popper & Hoxter, 1984). The question remains as to why McCauley and Kent (2012) found damage to sensory hair cells while Popper et al. (Popper et al., 2005) did not; however, there are many differences between the studies, including species and the precise sound source characteristics.

Hastings et al. (2008) exposed a fish with a swim bladder that is involved in hearing, the pinecone soldierfish (*Myripristis murdjan*), and three species that have a swim bladder that is not involved in hearing, the blue green damselfish (*Chromis viridis*), the saber squirrelfish (*Sargocentron spiniferum*), and the bluestripe seaperch (*Lutjanus kasmira*), to an air gun array. Fish in cages were exposed to multiple air gun shots with a cumulative sound exposure level of 190 dB re 1 µPa^2-s. The authors found no hearing loss in any fish examined up to 12 hours after the exposures.

In an investigation of another impulsive source, Casper et al. (2013b) found that some fishes may actually be more susceptible to barotrauma (e.g., swim bladder ruptures, herniations, and hematomas) than hearing effects when exposed to simulated impact pile driving. Hybrid striped bass (white bass [*Morone chrysops*] x striped bass [*Morone saxatilis*]) and Mozambique tilapia (*Oreochromis mossambicus*), two species with a swim bladder not involved in hearing, were exposed to sound exposure levels between 213 and 216 dB re 1 µPa^2-s. The subjects exhibited barotrauma and although researchers began to observe signs of inner ear hair cell loss, these effects were small compared to the other non-auditory injuries incurred. Researchers speculated that injury might occur prior to signs of hearing loss or TTS. These sound exposure levels may present the lowest threshold at which hearing effects may begin to occur.

Overall, PTS has not been known to occur in fishes tested to date. Any hearing loss in fish may be as temporary as the timeframe required to repair or replace the sensory cells that were damaged or destroyed (Popper et al., 2005; Popper et al., 2014; Smith et al., 2006). The lowest sound exposure level at which TTS has been observed in fishes with a swim bladder involved in hearing is 186 dB re 1 µPa^2-s. As reviewed in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), fishes without a swim bladder, or fishes with a swim bladder that is not involved in hearing, would be less susceptible to hearing loss (i.e., TTS) than fishes with swim bladders involved in hearing, even at higher levels and longer durations.

Hearing Loss due to Sonar and Other Transducers

Several studies have examined the effects of the sound exposures from low-frequency sonar on fish hearing (i.e., Halvorsen et al., 2013; Kane et al., 2010; Popper et al., 2007). Hearing was measured both immediately post exposure and for up to several days thereafter (Halvorsen et al., 2013; Kane et al., 2010; Popper et al., 2007). Maximum received sound pressure levels were 193 dB re 1 µPa for 324 or 648 seconds (a cumulative sound exposure level of 218 or 220 dB re 1 µPa^2-s, respectively) at frequencies ranging from 170 to 320 Hz (Kane et al., 2010; Popper et al., 2007) and 195 dB re 1 µPa for 324 seconds (a cumulative sound exposure level of 215 dB re 1 µPa^2-s) in a follow-on study (Halvorsen et al., 2013). Two species with a swim bladder not involved in hearing, the largemouth bass (*Micropterus salmoides*) and yellow perch (*Perca flavescens*), showed no loss in hearing sensitivity from sound exposure immediately after the test or 24 hours later. Channel catfish, a fish with a swim bladder involved in hearing, and some specimens of rainbow trout, a fish with a swim bladder not involved in hearing, showed a threshold shift (up to 10 to 20 dB of hearing loss) immediately after exposure to the low-frequency sonar when compared to baseline and control animals. Small thresholds shifts were detected for up to 24 hours after the experiment in some channel catfish. Although some rainbow trout showed signs of hearing loss, another group showed no hearing loss. The different results between rainbow trout test groups are difficult to understand, but may be due to development or genetic differences in the various groups of fish. Catfish hearing returned to, or close to, normal within about 24 hours after exposure to low-frequency sonar. Examination of the inner ears of the fish during necropsy revealed no differences from the control groups in ciliary bundles or other features indicative of hearing loss. The maximum time fish were held post exposure before sacrifice was 96 hours (Kane et al., 2010).

The same investigators examined the potential effects of mid-frequency active sonar on fish hearing and the inner ear (Halvorsen et al., 2012c; Kane et al., 2010). The maximum received sound pressure level was 210 dB re 1 µPa at a frequency of 2.8 to 3.8 kHz for a total duration of 15 seconds (cumulative sound exposure level of 220 dB re 1 μPa^2-s). Out of the species tested (rainbow trout and channel catfish), only one test group of channel catfish showed any hearing loss after exposure to mid-frequency active sonar. The investigators tested catfish during two different seasons and found that the group tested in October experienced TTS, which recovered within 24 hours, but fish tested in December showed no effect. It was speculated that the difference in hearing loss between catfish groups might have been due to the difference in water temperature during the testing period or due to differences between the two stocks of fish (Halvorsen et al., 2012c). Any effects on hearing in channel catfish due to sound exposure appeared to be short-term and non-permanent (Halvorsen et al., 2012c; Kane et al., 2010).

Some studies have suggested that there may be some loss of sensory hair cells due to high intensity sources, indicating a loss in hearing sensitivity; however, none of those studies concurrently investigated the subjects' actual hearing range after exposure to these sources. Enger (1981) found loss of ciliary bundles of the sensory cells in the inner ears of Atlantic cod following one to five hours of exposure to pure tone sounds between 50 and 400 Hz with a sound pressure level of 180 dB re 1 µPa. Hastings (1995) found auditory hair-cell damage in goldfish, a freshwater species with a swim bladder that is involved in hearing. Goldfish were exposed to 250 Hz and 500 Hz continuous tones with maximum peak sound pressure levels of 204 dB re 1 µPa and 197 dB re 1 µPa, respectively, for about two hours. Similarly, Hastings et al. (1996) demonstrated damage to some sensory hair cells in oscars (*Astronotus ocellatus*) observed one to four days following a one hour exposure to a pure tone at 300 Hz with a sound pressure level of 180 dB re 1 µPa, but no damage to the lateral line was observed. Both studies found a relatively small percentage of total hair cell loss from hearing organs despite long duration exposures. Effects from long-duration noise exposure studies are generally informative; however, they are not necessarily a direct comparison to intermittent short-duration sounds generated during Navy activities involving sonar and other transducers.

As noted in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), some fish species with a swim bladder that is involved in hearing may be more susceptible to TTS from high intensity non-impulsive sound sources, such as sonar and other transducers, depending on the duration and frequency content of the exposure. Fishes with a swim bladder involved in hearing and fishes with high-frequency hearing may exhibit TTS from exposure to low- and mid-frequency sonar, specifically at cumulative sound exposure levels above 215 dB re 1 µPa^2-s. Fishes without a swim bladder and fishes with a swim bladder that is not involved in hearing would be unlikely to detect mid- or other higher-frequency sonars and would likely require a much higher sound exposure level to exhibit the same effect from exposure to low-frequency active sonar.

Hearing Loss due to Vessel Noise

Little data exist on the effects of vessel noise on hearing in fishes. However, TTS has been observed in fishes exposed to elevated background noise and other non-impulsive sources (e.g., white noise). Caged studies on pressure-sensitive fishes (i.e., fishes with a swim bladder involved in hearing and those with high-frequency hearing) show some hearing loss after several days or weeks of exposure to increased background sounds, although the hearing loss seems to recover (e.g., Scholik & Yan, 2002a; Smith et al., 2004a; Smith et al., 2006). Smith et al. (2004a; 2006) exposed goldfish to noise with a sound pressure level of 170 dB re 1 µPa and found a clear relationship between the amount of hearing loss and the duration of exposure until maximum hearing loss occurred at about 24 hours of exposure. A 10-minute exposure resulted in 5 dB of TTS, whereas a three-week exposure resulted in a 28 dB TTS that took over two weeks to return to pre-exposure baseline levels (Smith et al., 2004a). Recovery times were not measured by investigators for shorter exposure durations. It is important to note that these exposures were continuous and subjects were unable to avoid the sound source for the duration of the experiment.

Scholik and Yan (2001) demonstrated TTS in fathead minnows (*Pimephales promelas*), another pressure sensitive species with similar hearing capabilities as the goldfish, after a 24-hour continuous exposure to white noise (0.3 to 2.0 kHz) at 142 dB re 1 µPa, that did not recover 14 days post exposure. This is the longest threshold shift documented to have occurred in a fish species, with the actual duration of the threshold shift being unknown but exceeding 14 days. However, the same authors found that the bluegill sunfish (*Lepomis macrochirus*), a species that primarily detects particle motion and lacks specializations for hearing, did not show statistically significant elevations in auditory thresholds when exposed to the same stimulus (Scholik & Yan, 2002b). This demonstrates that fishes with a swim bladder involved in hearing and those with high-frequency hearing may be more sensitive to hearing loss than fishes without a swim bladder or those with a swim bladder not involved in hearing. Studies such as these should be treated with caution in comparison to exposures in a natural environment, largely due to the confined nature of the controlled setting where fishes are unable to avoid the sound source (e.g., fishes held stationary in a tub), and due to the long, continuous durations of the exposures themselves (sometimes days to weeks). Fishes that are exposed to vessel noise in their natural environment, even in areas with higher levels of vessel movement, would only be exposed for a short duration (seconds or minutes) as vessels are transient and pass by.

As summarized in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), some fish species with a swim bladder that is involved in hearing may be more susceptible to TTS from long duration continuous noise, such as broadband[2] white noise, depending on the duration of the exposure (thresholds are proposed based on continuous exposure of 12 hours). However, it is not likely that TTS would occur in fishes with a swim bladder not involved in hearing or in fishes without a swim bladder.

[2] A sound or signal that contains energy across multiple frequencies.

3.6.3.1.1.3 Masking

Masking refers to the presence of a noise that interferes with a fish's ability to hear biologically important sounds including those produced by prey, predators, or other fishes. Masking occurs in all vertebrate groups and can effectively limit the distance over which an animal can communicate and detect biologically relevant sounds. Human-generated continuous sounds (e.g., some sonar, vessel noise and vibratory pile driving) have the potential to mask sounds that are biologically important to fishes. Researchers have studied masking in fishes using continuous masking noise but masking due to intermittent, short duty cycle sounds has not been studied. Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) provides additional information on masking and the framework used to analyze this potential impact.

Masking is likely to occur in most fishes due to varying levels of ambient or natural noise in the environment such as wave action, precipitation, or other animal vocalizations (Popper et al., 2014). Ambient noise during higher sea states in the ocean has resulted in elevated thresholds in several fish species (Chapman & Hawkins, 1973; Ramcharitar & Popper, 2004). Although the overall intensity or loudness of ambient or human-generated noise may result in masking effects in fishes, masking may be most problematic when human-generated signals or ambient noise levels overlap the frequencies of biologically important signals (Buerkle, 1968, 1969; Popper et al., 2014; Tavolga, 1974)

Wysocki and Ladich (2005) investigated the influence of continuous white noise exposure on the auditory sensitivity of two freshwater fish with notable hearing specializations for sound pressure detection, the goldfish and the lined Raphael catfish (*Platydoras costatus*), and a freshwater fish without notable specializations, the pumpkinseed sunfish (*Lepomis gibbosus*). For the goldfish and catfish, baseline thresholds were lower than masked thresholds. Continuous white noise with a sound pressure level of approximately 130 dB re 1 µPa at 1 m resulted in an elevated threshold of 23 to 44 dB within the subjects' region of best sensitivity between 500 and 1000 Hz. There was less evidence of masking in the sunfish during the same exposures with only a shift of 11 dB. Wysocki and Ladich (2005) suggest that ambient sound regimes may limit acoustic communication and orientation, especially in animals with notable hearing specializations for sound pressure detection.

Masking could lead to potential fitness costs depending on the severity of the reaction (Radford et al., 2014; Slabbekoorn et al., 2010). For example, masking could result in changes in predator-prey relationships potentially inhibiting a fish's ability to detect predators and therefore increase its risk of predation (Astrup, 1999; Mann et al., 1998; Simpson et al., 2015; Simpson et al., 2016). Masking may also limit the distance over which fish can communicate or detect important signals (Codarin et al., 2009; Ramcharitar et al., 2001; Ramcharitar et al., 2006), including sounds emitted from a reef for navigating larvae (Higgs, 2005; Neenan et al., 2016). If the masking signal is brief (a few seconds or less), biologically important signals may still be detected, resulting in little effect to the individual. If the signal is longer in duration (minutes or hours) or overlaps with important frequencies for a particular species, more severe consequences may occur such as the inability to attract a mate and reproduce. Holt and Johnston (2014) were the first to demonstrate the Lombard effect in one species of fish, a potentially compensatory behavior where an animal increases the source level of its vocalizations in response to elevated noise levels. The Lombard effect is currently understood to be a reflex which may be unnoticeable to the animal or may lead to increased energy expenditure during communication.

The *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014) highlights a lack of data that exist for masking by sonar but suggests that the narrow bandwidth and intermittent nature of most sonar signals would result in only a limited probability of any masking effects. In addition, most sonars (mid-, high-, and very high-frequency) are above the hearing range of most marine fish species, eliminating the possibility of masking for these species. In most cases, the probability of masking would further decrease with increasing distance from the sound source.

In addition, no data are available on masking by impulsive signals (e.g., impact pile driving and air guns) (Popper et al., 2014). Impulsive sounds are typically brief, lasting only fractions of a second, where masking could occur only during that brief duration of sound. Biological sounds can typically be detected between pulses within close distances to the source unless those biological sounds are similar to the masking noise, such as impulsive or drumming vocalizations made by some fishes (e.g., cod or haddock). Masking could also indirectly occur because of repetitive impulsive signals where the repetitive sounds and reverberations over distance may create a more continuous noise exposure.

Although there is evidence of masking as a result of exposure to vessel noise, the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014) does not present numeric thresholds for this effect. Instead, relative risk factors are considered and it is assumed the probability of masking occurring is higher at near to moderate distances from the source (up to hundreds of meters) but decrease with increasing distance (Popper et al., 2014).

3.6.3.1.1.4 Physiological Stress

Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) provides additional information on physiological stress and the framework used to analyze this potential impact. A fish must first be able to detect a sound above its hearing threshold and above the ambient noise level before a physiological stress reaction can occur. The initial response to a stimulus is a rapid release of stress hormones into the circulatory system, which may cause other responses such as elevated heart rate and blood chemistry changes. Although an increase in background sound has been shown to cause stress in humans and animals, only a limited number of studies have measured biochemical responses by fishes to acoustic stress (e.g., Goetz et al., 2015; Madaro et al., 2015; Remage-Healey et al., 2006; Smith et al., 2004b; Wysocki et al., 2006; Wysocki et al., 2007) and the results have varied. Researchers have studied physiological stress in fishes using predator vocalizations, non-impulsive or continuous, and impulsive noise exposures.

A stress response that has been observed in fishes includes the production of cortisol (a stress hormone) when exposed to sounds such as boat noise, tones, or predator vocalizations. Nichols et al. (2015) found that giant kelpfish (*Heterostichus rostratus*) had increased levels of cortisol with increased sound level and intermittency of boat noise playbacks. Cod exposed to a short-duration upsweep (a tone that sweeps upward across multiple frequencies) across 100 to 1,000 Hz had increases in cortisol levels, which returned to normal within one hour post-exposure (Sierra-Flores et al., 2015). Remage-Healey et al. (2006) found elevated cortisol levels in Gulf toadfish (*Opsanus beta*) exposed to low-frequency bottlenose dolphin sounds. The researchers observed none of these effects in toadfish exposed to low-frequency snapping shrimp "pops."

A sudden increase in sound pressure level or an increase in overall background noise levels can increase hormone levels and alter other metabolic rates indicative of a stress response, such as increased ventilation and oxygen consumption (Pickering, 1981; Popper & Hastings, 2009b; Simpson et al., 2015; Simpson et al., 2016; Smith et al., 2004a, 2004b). Similarly, reef fish embryos exposed to boat noise have shown increases in heart rate, another indication of a physiological stress response (Jain-Schlaepfer et al., 2018). Although results have varied, it has been shown that chronic or long-term (days or weeks) exposures of continuous man-made sounds can lead to a reduction in embryo viability (Sierra-Flores et al., 2015) and slowed growth rates (Nedelec et al., 2015).

However, not all species tested to date show these reactions. Smith et al. (2004b) found no increase in corticosteroid, a class of stress hormones, in goldfish exposed to a continuous, band-limited noise (0.1–10 kHz) with a sound pressure level of 170 dB re 1 µPa for one month. Wysocki et al. (2007) exposed rainbow trout to continuous band-limited noise with a sound pressure level of about 150 dB re 1 µPa for nine months with no observed stress effects. Growth rates and effects on the trout's immune systems were not significantly different from control animals held at a sound pressure level of 110 dB re 1 µPa.

Fishes may have physiological stress reactions to sounds that they can hear. Generally, stress responses are more likely to occur in the presence of potentially threatening sound sources, such as predator vocalizations, or during the sudden onset of impulsive signals rather than from non-impulsive or continuous sources such as vessel noise or sonar. Stress responses are typically brief (a few seconds to minutes) if the exposure is short or if fishes habituate or learn to tolerate the noise that is being presented. Exposure to chronic noise sources can lead to more severe impacts such as reduced growth rates, which may lead to reduced survivability for an individual. It is assumed that any physiological response (e.g., hearing loss or injury) or significant behavioral response is also associated with a stress response.

3.6.3.1.1.5 Behavioral Reactions

Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) provides additional information on behavioral reactions and the framework used to analyze this potential impact. Behavioral reactions in fishes have been observed due to a number of different types of sound sources. The majority of research has been performed using air guns (including large-scale seismic surveys), sonar, and vessel noise. Fewer observations have been made on behavioral reactions to impact pile driving noise; although fish are likely to show similar behavioral reactions to any impulsive noise within or outside the zone for hearing loss and injury.

As with masking, a fish must first be able to detect a sound above its hearing threshold and above the ambient noise level before a behavioral reaction can potentially occur. Most fishes can only detect low-frequency sounds with the exception of a few species that can detect some mid and high frequencies (above 1 kHz).

Studies of fishes have identified the following basic behavioral reactions to sound: alteration of natural behaviors (e.g., startle or alarm), and avoidance (LGL Ltd Environmental Research Associates et al., 2008; McCauley et al., 2000; Pearson et al., 1992). In the context of this FEIS/OEIS, and to remain consistent with available behavioral reaction literature, the terms "startle" and "alarm" and "response" or "reactions" will be used synonymously.

In addition, observed behavioral effects to fish could include disruption to or alteration of natural activities such as swimming, schooling, feeding, breeding, and migrating. Sudden changes in sound level can cause fish to dive, rise, or change swimming direction. However, there is evidence that some fish may habituate to repeated exposures or learn to tolerate noise that is not seemingly unthreatening (e.g., Bruintjes et al., 2016; Nedelec et al., 2016b; Radford et al., 2016).

Changes in sound intensity may be more important to a fishes' behavior than the maximum sound level. Sounds that fluctuate in level or have intermittent pulse rates tend to elicit stronger responses from fish than even stronger sounds with a continuous level (Neo et al., 2014; Schwarz & Greer, 1984).

Interpreting behavioral responses can be difficult due to species-specific behavioral tendencies, motivational state (e.g., feeding or mating), an individual's previous experience, and whether or not the fish are able to avoid the source (e.g., caged versus free-swimming subjects). Results from caged studies may not provide a clear understanding of how free-swimming fishes may react to the same or similar sound exposures (Hawkins et al., 2015).

Behavioral Reactions due to Impulsive Sound Sources

It is assumed that most species would react similarly to impulsive sources (i.e., air guns and impact pile driving). These reactions include startle or alarm responses and increased swim speeds at the onset of impulsive sounds (Fewtrell & McCauley, 2012; Pearson et al., 1992; Roberts et al., 2016). Data on behavioral reactions in fishes exposed to impulsive sound sources is mostly limited to studies using caged fishes and the use of seismic air guns (Løkkeborg et al., 2012). Several species of rockfish (*Sebastes* species) in a caged environment exhibited startle or alarm reactions to seismic air gun pulses between peak-to-peak sound pressure levels of 180 dB re 1 µPa and 205 dB re 1 µPa (Pearson et al., 1992). More subtle behavioral changes were noted at lower sound pressure levels, including decreased swim speeds. At the presentation of the sound, some species of rockfish settled to the bottom of the experimental enclosure and reduced swim speed. Trevally (*Pseudocaranx dentex*) and pink snapper (*Pagrus auratus*) also exhibited alert responses as well as changes in swim depth, speed, and schooling behaviors when exposed to air gun noise (Fewtrell & McCauley, 2012). Both trevally and pink snapper swam faster and closer to the bottom of the cage at the onset of the exposure. However, trevally swam in tightly cohesive groups at the bottom of the test cages while pink snapper exhibited much looser group cohesion. These behavioral responses were seen during sound exposure levels as low as 147 up to 161 dB re 1 µPa^2-s but habituation occurred in all cases, either within a few minutes or up to 30 minutes after the final air gun shot (Fewtrell & McCauley, 2012; Pearson et al., 1992).

Some studies have shown a lack of behavioral reactions to air gun noise. Herring exposed to an approaching air gun survey (from 27 to 2 km over six hours), resulting in single pulse sound exposure levels of 125 to 155 dB re 1 µPa^2-s, did not react by changing direction or swim speed (Pena et al., 2013). Although these levels are similar to those tested in other studies which exhibited responses (Fewtrell & McCauley, 2012), the distance of the exposure to the test enclosure, the slow onset of the sound source, and a strong motivation for feeding may have affected the observed response (Pena et al., 2013). In another study, Wardle et al. (2001) observed marine fish on an inshore reef before, during, and after an air gun survey at varying distances. The air guns were calibrated at a peak level of 210 dB re 1 µPa at 16 m and 195 dB re 1 µPa at 109 m from the source. Other than observed startle responses and small changes in position of pollack, when the air gun was located within close proximity to the test site (within 10 m), they found no substantial or permanent changes in the behavior of the fish on the reef throughout the course of the study. Behavioral responses to impulsive sources are more likely to occur within near and intermediate (tens to hundreds of meters) distances from the source as opposed to far distances (thousands of meters) (Popper et al., 2014).

Unlike the previous studies, Slotte et al. (2004) used fishing sonar (38 kHz echo sounder) to monitor behavior and depth of blue whiting (*Micromesistius poutassou*) and Norwegian spring herring (*Claupea harengus L.*) spawning schools exposed to air gun signals. They reported that fishes in the area of the air guns appeared to go to greater depths after the air gun exposure compared to their vertical position prior to the air gun usage. Moreover, the abundance of animals 30–50 km away from the air guns increased during seismic activity, suggesting that migrating fish left the zone of seismic activity and did not re-enter the area until the activity ceased. It is unlikely that either species was able to detect the fishing sonar, however, it should be noted that these behavior patterns may have also been influenced by other factors such as motivation for feeding, migration, or other environmental factors (e.g., temperature, salinity, etc.) (Slotte et al., 2004). In a similar study, overall abundance of multiple species of reef fish decreased at a site monitored with video cameras approximately 8 km away from a seismic survey. This decrease was noted in comparison to abundances monitored on three consecutive days prior to the start of the survey. Received levels of the air gun signals and monitoring of other areas surrounding the reef were not completed during this study, so it is not known how loud the signals were on the reef, or whether fishes avoided the area completely or simply moved to a close by reef (Paxton et al., 2017).

Alterations in natural behavior patterns due to exposure to pile driving noise have not been studied as thoroughly, but reactions noted thus far are similar to those seen in response to seismic surveys. These changes in behavior include startle responses, changes in depth (in both caged and free-swimming subjects), increased swim speeds, changes in ventilation rates, directional avoidance, and changes in social behaviors such as shoaling and distance from neighboring fish (observed in caged fish) (e.g., Hawkins et al., 2014; Herbert-Read et al., 2017; Mueller-Blenkle et al., 2010; Neo et al., 2015; Roberts et al., 2016). The severity of response varied greatly by species and received sound pressure level of the exposure. For example, some minor behavioral reactions, such as startle responses, were observed during caged studies with a sound pressure level as low as 140 dB re 1 µPa (Neo et al., 2014). However, only some free-swimming fishes avoided pile driving noise at even higher sound pressure levels between 152 and 157 dB re 1 µPa (Iafrate et al., 2016). In addition, Roberts et al. (2016) observed that although multiple species of free swimming fish responded to simulated pile driving recordings, not all responded consistently and, in some cases, only one fish would respond while the others continued feeding from a baited remote underwater video. Other fish responded to different strikes. The repetition rate of pulses during an exposure may also have an effect on what behaviors were noted and how quickly these behaviors recovered as opposed to the overall sound pressure or exposure level. For example, Neo et al. (2014) observed slower recovery times in fishes exposed to intermittent sounds (similar to pile driving) compared to continuous exposures.

As summarized in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), species may react differently to the same sound source depending on a number of variables, such as the animal's life stage or behavioral state (e.g., feeding, mating). Without specific data, it is assumed that fishes react similarly to all impulsive sounds outside the zone for hearing loss and injury. Observations of fish reactions to large-scale air gun surveys are informative, but not necessarily directly applicable to analyzing impacts from the short-term, intermittent use of all impulsive sources. It is assumed that fish have a high probability of reacting to an impulsive sound source within near and intermediate distances (tens to hundreds of meters), and a decreasing probability of reaction at increasing distances (Popper et al., 2014).

Behavioral Reactions due to Sonar and Other Transducers

Behavioral reactions to sonar have been studied both in caged and free-swimming fish although results can oftentimes be difficult to interpret depending on the species tested and the study environment. Jørgensen et al. (2005) showed that caged cod and spotted wolf fish (*Anarhichas minor*) lacked any response to simulated sonar between 1 and 8 kHz. However, within the same study, reactions were seen in juvenile herring. It is likely that the sonar signals were inaudible to the cod and wolf fish (species that lack notable hearing specializations), but audible to herring which do possess hearing capabilities in the frequency ranges tested.

Doksæter et al. (2009; 2012) and Sivle et al. (2012; 2014) studied the reactions of both wild and captive Atlantic herring to the Royal Netherlands Navy's experimental mid-frequency active sonar ranging from 1 to 7 kHz. The behavior of the fish was monitored in each study either using upward looking echosounders (for wild herring) or audio and video monitoring systems (for captive herring). The source levels used within each study varied across all studies and exposures with a maximum received sound pressure level of 181 dB re 1 µPa and maximum cumulative sound exposure level of 184 dB re 1 $\mu Pa^2 \cdot s$. No avoidance or escape reactions were observed when herring were exposed to any sonar sources. Instead, significant reactions were noted at lower received sound levels of different non-sonar sound types. For example, dive responses (i.e., escape reactions) were observed when herring were exposed to killer whale feeding sounds at received sound pressure levels of approximately 150 dB re 1 µPa (Sivle et al., 2012). Startle responses were seen when the cages for captive herring were hit with a wooden stick and with the ignition of an outboard boat engine at a distance of one meter from the test pen (Doksaeter et al., 2012). It is possible that the herring were not disturbed by the sonar, were more motivated to continue other behaviors such as feeding, or did not associate the sound as a threatening stimulus. Based on these results (Doksaeter et al., 2009; Doksaeter et al., 2012; Sivle et al., 2012), Sivle et al. (2014) created a model in order to report on the possible population-level effects on Atlantic herring from active naval sonar. The authors concluded that the use of naval sonar poses little risk to populations of herring regardless of season, even when the herring populations are aggregated and directly exposed to sonar.

There is evidence that elasmobranchs (cartilaginous fish, including sharks and rays) also respond to human-generated sounds. Myrberg and colleagues did experiments in which they played back sounds (e.g., pulsed tones below 1 kHz) and attracted a number of different shark species to the sound source (e.g., Casper et al., 2012a; Myrberg et al., 1976; Myrberg et al., 1969; Myrberg et al., 1972; Nelson & Johnson, 1972). The results of these studies showed that sharks were attracted to irregularly pulsed low-frequency sounds (below several hundred Hz), in the same frequency range of sounds that might be produced by struggling prey. However, sharks are not known to be attracted to continuous signals or higher frequencies that they presumably cannot hear (Casper & Mann, 2006; Casper & Mann, 2009).

Only a few species of marine fishes can detect sonars above 1 kHz (see Section 3.6.2.1.3, Hearing and Vocalization), meaning that most fishes would not detect most mid-, high-, or very high-frequency Navy sonars. The few marine species that can detect above 1 kHz and have some hearing specializations may be able to better detect the sound and would therefore be more likely to react. However, researchers have found little reaction by adult fish in the wild to sonars within the animals' hearing range (Doksaeter et al., 2009; Doksaeter et al., 2012; Sivle et al., 2012). The *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014) suggests that fish able to hear sonars would have a low probability of reacting to the source within near or intermediate distances (within tens to hundreds of meters) and a decreasing probability of reacting at increasing distances.

Behavioral Reactions due to Vessel Noise

Vessel traffic also contributes to the amount of noise in the ocean and has the potential to affect fishes. Several studies have demonstrated and reviewed avoidance responses by fishes (e.g., herring and cod) to the low-frequency sounds of vessels (De Robertis & Handegard, 2013; Engås et al., 1995; Handegard et al., 2003). Misund (1997) found fish ahead of a ship that showed avoidance reactions did so at ranges of 50 to 150 m. When the vessel passed over them, some species of fish responded with sudden escape responses that included lateral avoidance or downward compression of the school.

As mentioned in Section 3.6.3.1.1.5 (Behavioral Reactions), behavioral reactions are quite variable and depend on a number of factors such as (but not limited to) the type of fish, its life history stage, behavior, time of day, location, the type of vessel, and the sound propagation characteristics of the water column (Popper et al., 2014; Schwarz & Greer, 1984). Reactions to playbacks of continuous noise or passing vessels generally include basic startle and avoidance responses, as well as evidence of distraction and increased decision-making errors. Other specific examples of observed responses include increased group cohesion, changes in vertical distribution in the water column, and changes in swim speeds, as well as changes in feeding efficacy such as reduced foraging attempts and increased mistakes (i.e., lowered discrimination between food and non-food items) (e.g., Bracciali et al., 2012; De Robertis & Handegard, 2013; Handegard et al., 2015; Nedelec et al., 2015; Nedelec et al., 2017; Neo et al., 2015; Payne et al., 2015; Purser & Radford, 2011; Roberts et al., 2016; Sabet et al., 2016; Simpson et al., 2015; Simpson et al., 2016; Voellmy et al., 2014a; Voellmy et al., 2014b). As mentioned above, responses may also be dependent on the type of vessel fish are exposed to. For example, juvenile damselfish (*Pomacentrus wardi*) exposed to sound from a two stroke engine resulted in startle responses, reduction in boldness (increased time spent hiding, less time exhibiting exploratory behaviors), space use (maximum distance ventured from shelter), as well as more conservative reactions to visual stimuli analogous to a potential predator. However, damselfish exposed to sound from a four stroke engine generally displayed similar responses as control fish exposed to ambient noise (e.g., little or no change in boldness) (McCormick et al., 2018).

Changes in anti-predator response have also been observed but vary by species. During exposures to vessel noise, juvenile Ambon damselfish (*Pomacentrus amboinensis*) and European eels showed slower reaction times and lacked startle responses to predatory attacks, and subsequently showed signs of distraction and increased their risk of predation during both simulated and actual predation experiments (Simpson et al., 2015; Simpson et al., 2016). Spiny chromis (*Acanthochromis polyacanthus*) exposed to chronic boat noise playbacks spent less time feeding and interacting with offspring, and increased defensive acts. In addition, offspring survival rates were also lower at nests exposed to chronic boat noise playbacks versus those exposed to ambient playbacks (Nedelec et al., 2017). This suggests that chronic or long-term (up to 12 consecutive days) exposures could have more severe consequences than brief exposures.

In contrast, larval Atlantic cod showed a stronger anti-predator response and were more difficult to capture during simulated predator attacks (Nedelec et al., 2015). There are also observations of a general lack of response to shipping and pile driving playback noise by grey mullet (*Chelon labrosus*) and two-spotted gobys (*Gobiusculus flavescens*) (Roberts et al., 2016). Mensinger et al. (2018) found that Australian snapper (*Pagrus auratus*) located in a protected area showed no change in feeding behavior or avoidance during boat passes, whereas snapper in areas where fishing occurs startled and ceased feeding behaviors during boat presence. This supports that location and past experience also have an influence on whether fishes react.

Although behavioral responses such as those listed above were often noted during the onset of most sound presentations, most behaviors did not last long and animals quickly returned to baseline behavior patterns. In fact, in one study, when given the chance to move from a noisy tank (with sound pressure levels reaching 120–140 dB re 1 μPa) to a quieter tank (sound pressure levels of 110 dB re 1 μPa), there was no evidence of avoidance. The fish did not seem to prefer the quieter environment and continued to swim between the two tanks comparable to control sessions (Neo et al., 2015). However, many of these reactions are difficult to extrapolate to real world conditions due to the captive environment in which testing occurred.

Most fish species should be able to detect vessel noise due to its low-frequency content and their hearing capabilities (see Section 3.6.2.1.3, Hearing and Vocalization). The *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014) suggests that fishes have a high to moderate probability of reacting to nearby vessel noise (i.e., within tens of meters) with decreasing probability of reactions with increasing distance from the source (hundreds or more meters).

3.6.3.1.1.6 Long-term Consequences

Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) provides additional information on potential pathways for long-term consequences. Mortality removes an individual fish from the population and injury reduces the fitness of an individual. Few studies have been conducted on any long-term consequences from repeated hearing loss, stress, or behavioral reactions in fishes due to exposure to loud sounds (Hawkins et al., 2015; Popper & Hastings, 2009b; Popper et al., 2014). Repeated exposures of an individual to multiple sound-producing activities over a season, year, or life stage could cause reactions with costs that can accumulate over time to cause long-term consequences for the individual. These long-term consequences may affect the survivability of the individual, or if impacting enough individuals may have population-level effects, including alteration from migration paths, avoidance of important habitat, or even cessation of foraging or reproductive behavior (Hawkins et al., 2015). Conversely, some animals habituate to or become tolerant of repeated exposures over time, learning to ignore a stimulus that in the past has not accompanied any overt threat. In fact, Sivle et al. (2016) predicted that exposures to sonar at the maximum levels tested would only result in short-term disturbance and would not likely affect the overall population in sensitive fishes such as herring.

3.6.3.1.2 Impacts from Sonar and Other Transducers

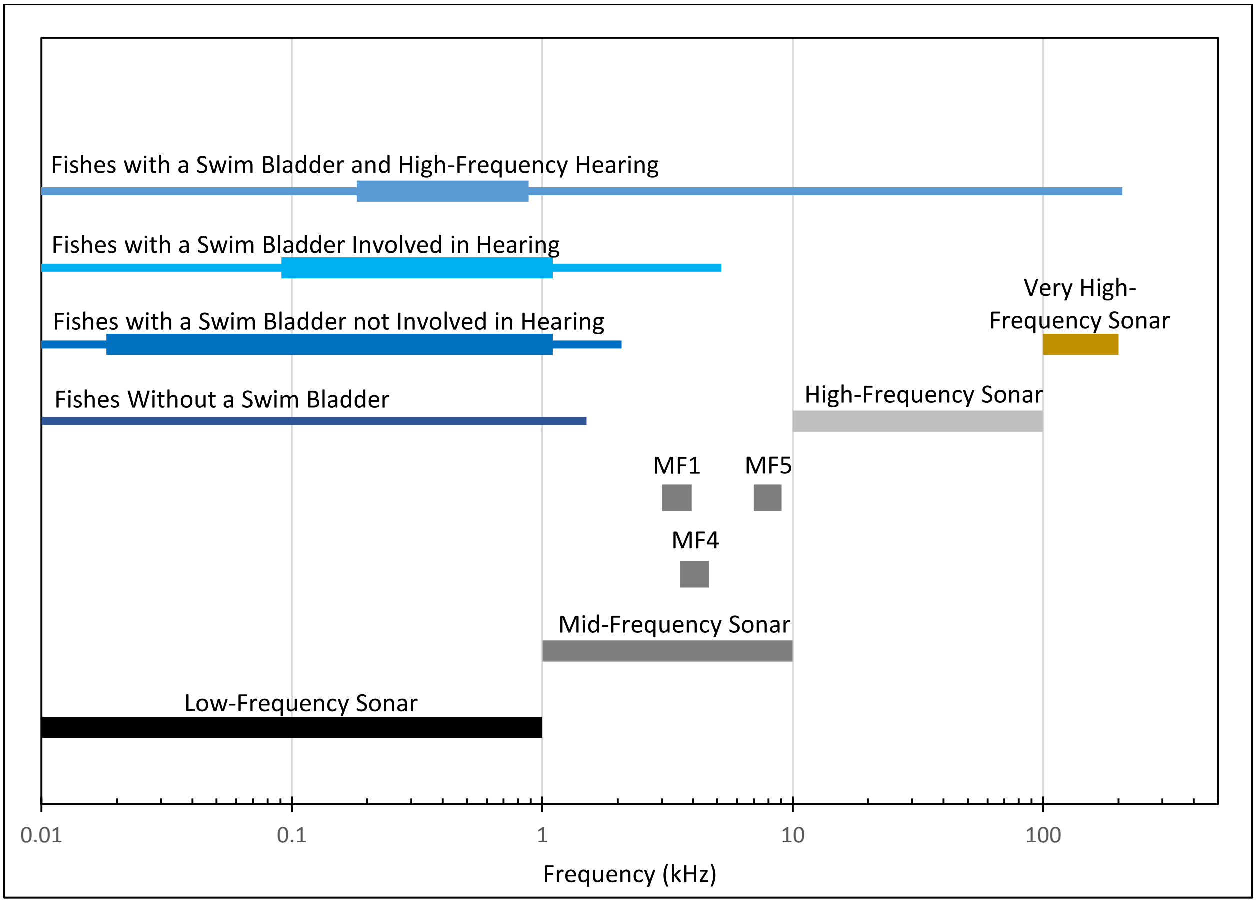
Sonar and other transducers proposed for use are transient in most locations because activities that involve sonar and other transducers take place at different locations throughout the Study Area. A few activities involving sonar and other transducers occur in inshore waters (within bays and estuaries), including at pierside locations. Sonar and other transducers emit sound waves into the water to detect objects, safely navigate, and communicate. General categories and characteristics of these systems and the number of hours these sonars will be operated are described in Section 3.0.3.3 (Identifying Stressors for Analysis). The activities analyzed in the EIS/OEIS that use sonar and other transducers are described in Appendix A (Navy Activity Descriptions).

As described under Section 3.6.3.1.1.1 (Injury - Injury due to Sonar and Other Transducers), direct injury from sonar and other transducers is highly unlikely because injury has not been documented in fish exposed to sonar (Halvorsen et al., 2012c; Halvorsen et al., 2013; Popper et al., 2007) and therefore is not considered further in this analysis.

Fishes are not equally sensitive to noise at all frequencies. Fishes must first be able to hear a sound in order to be affected by it. As discussed in Section 3.6.2.1.3 (Hearing and Vocalization), many marine fish species tested to date hear primarily below 1 kHz. For the purposes of this analysis, fish species were grouped into one of four fish hearing groups based on either their known hearing ranges (i.e., audiograms) or physiological features that may be linked to overall hearing capabilities (i.e., swim bladder with connection to, or in close proximity to, the inner ear). Figure 3.6 2 provides a summary of hearing threshold data from available literature (e.g., Casper & Mann, 2006; Deng et al., 2013; Kéver et al., 2014; Mann et al., 2001; Ramcharitar et al., 2006) to demonstrate the maximum potential range of frequency detection for each hearing group.

Due to data limitations, these estimated hearing ranges may be overly conservative in that they may extend beyond what some species within a given fish hearing group may actually detect. For example, although most sharks are sensitive to lower frequencies, well below 1 kHz, the bull shark has been tested and can detect frequencies up to 1.5 kHz (Kritzler & Wood, 1961; Myrberg, 2001) and therefore represents the uppermost known limit of frequency detection for this hearing group. These upper bound of each fish hearing group's frequency range is outside of the range of best sensitivity for all fishes within that group. As a result, fishes within each group would only be able to detect those upper frequencies at close distances to the source, and from sources with relatively high source levels.

Figure 3.6-2 is not intended as a composite audiogram but rather displays the basic overlap in potential frequency content for each hearing group with Navy defined sonar classes (i.e., low-, mid-, high- and very high-frequency) as discussed under Section 3.0.3.3.1.1 (Sonar and Other Transducers – Classification of Sonar and Other Transducers).



Notes: Thin blue lines represent the estimated minimum and maximum range of frequency detection for each group. All hearing groups are assumed to hear down to 0.01 kHz regardless of available data. Thicker portions of each blue line represent the estimated minimum and maximum range of best sensitivity for that group. Currently, no data are available to estimate the range of best sensitivity for fishes without a swim bladder. Although each sonar class is represented graphically by the horizontal black, grey and brown bars, not all sources within each class would operate at all the displayed frequencies. Example mid-frequency sources are provided to further demonstrate this. kHz = kilohertz, MF1 = 3.5 kHz, MF4 = 4 kHz, MF5 = 8 kHz.

Figure 3.6-2: Fish Hearing Group and Navy Sonar Bin Frequency Ranges

Systems within the low-frequency sonar class present the greatest potential for overlap with fish hearing. Some mid-frequency sonars and other transducers may also overlap some species' hearing ranges, but to a lesser extent than low-frequency sonars. For example, the only hearing groups that have the potential to be able to detect mid-frequency sources within bins MF1, MF4 and MF5 are fishes with a swim bladder involved in hearing and with high-frequency hearing. It is anticipated that most marine fishes would not hear or be affected by mid-frequency Navy sonars or other transducers with operating frequencies greater than about 1–4 kHz. Only a few fish species (i.e., fish with a swim bladder and high-frequency hearing specializations) can detect and therefore be potentially affected by high- and very high-frequency sonars and other transducers.

The most probable impacts from exposure to sonar and other transducers are TTS (for more detail see Section 3.6.3.1.1.2, Hearing Loss), masking (for more detail see Section 3.6.3.1.1.3, Masking), physiological stress (for more detail see Section 3.6.3.1.1.4, Physiological Stress), and behavioral reactions (for more detail see Section 3.6.3.1.1.5, Behavioral Reactions). Analysis of these effects is provided below.

3.6.3.1.2.1 Methods for Analyzing Impacts from Sonar and Other Transducers

The Navy performed a quantitative analysis to estimate the range to TTS for fishes exposed to sonar and other transducers used during Navy training and testing activities. Inputs to the quantitative analysis included sound propagation modeling in the Navy's Acoustic Effects Model to the sound exposure criteria and thresholds presented below. Although ranges to effect are predicted, density data for fish species within the Study Area are not available; therefore, it is not possible to estimate the total number of individuals that may be affected by sound produced by sonar and other transducers.

Criteria and thresholds to estimate impacts from sonar and other transducers are presented below in Table 3.6-3. Thresholds for hearing loss are typically reported in cumulative sound exposure level so as to account for the duration of the exposure. Therefore, thresholds reported in the ANSI Sound Exposure Guideline technical report (Popper et al., 2014) that were presented in other metrics were converted to sound exposure level based on the signal duration reported in the original studies (see Halvorsen et al., 2012c; Halvorsen et al., 2013; Kane et al., 2010; Popper et al., 2007). General research findings from these studies can be reviewed in Section 3.6.3.1.1.2 (Hearing Loss).

Table 3.6-3: Sound Exposure Criteria for TTS from Sonar

Fish Hearing Group	*TTS from Low-Frequency Sonar (SEL_{cum})*	*TTS from Mid-Frequency Sonar (SEL_{cum})*
Fishes without a swim bladder	NC	NC
Fishes with a swim bladder not involved in hearing	> 210	NC
Fishes with a swim bladder involved in hearing	210	220
Fishes with a swim bladder and high-frequency hearing	210	220

Notes: TTS = Temporary Threshold Shift, SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micropascal squared seconds [dB re 1 μPa^2-s]), NC = effects from exposure to sonar is considered to be unlikely, therefore no criteria are reported, ">" indicates that the given effect would occur above the reported threshold.

For mid-frequency sonars, fishes with a swim bladder involved in hearing have shown signs of hearing loss because of mid-frequency sonar exposure at a maximum received sound pressure level of 210 dB re 1 µPa for a total duration of 15 seconds. To account for the total duration of the exposure, the threshold for TTS is a cumulative sound exposure level of 220 dB re 1 μPa^2-s (Halvorsen et al., 2012c; Kane et al., 2010). The same threshold is used for fishes with a swim bladder and high-frequency hearing as a conservative measure although fishes in this hearing group have not been tested for the same impact. TTS has not been observed in fishes with a swim bladder that is not involved in hearing exposed to mid-frequency sonar. Fishes within this hearing group do not sense pressure well and typically cannot hear at frequencies above 1 kHz (Halvorsen et al., 2012c; Popper et al., 2014). Therefore, no criteria were proposed for fishes with a swim bladder that is not involved in hearing from exposure to mid-frequency sonars as it is considered unlikely for TTS to occur. Fishes without a swim bladder are even less susceptible to noise exposure; therefore, TTS is unlikely to occur, and no criteria are proposed for this group either.

For low-frequency sonar, as described in Section 3.6.3.1.1.2 (Hearing Loss), exposure of fishes with a swim bladder has resulted in TTS (Halvorsen et al., 2013; Kane et al., 2010; Popper et al., 2007). Specifically, fishes with a swim bladder not involved in hearing showed signs of hearing loss after exposure to a maximum received sound pressure level of 193 dB re 1 µPa for 324 and 648 seconds (cumulative sound exposure level of 218 and 220 dB re 1 μPa^2-s, respectively) (Kane et al., 2010; Popper et al., 2007). In addition, exposure of fishes with a swim bladder involved in hearing to low-frequency sonar at a sound pressure level of 195 dB re 1 µPa for 324 seconds (cumulative sound exposure level of 215 dB re 1 μPa^2-s) resulted in TTS (Halvorsen et al., 2013). Although the results were variable, it can be assumed that TTS may occur in fishes within the same hearing groups at similar exposure levels. As a conservative measure, the threshold for TTS from exposure to low-frequency sonar for all fish hearing groups with a swim bladder was rounded down to a cumulative sound exposure level of 210 dB re 1 μPa^2-s.

Criteria for high- and very high-frequency sonar were not available in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014); however, only species with a swim bladder involved in hearing and with high-frequency specializations, such as shad, could potentially be affected. The majority of fish species within the Study Area are unlikely to be able to detect these sounds. There is little data available on hearing loss from exposure of fishes to these high-frequency sonars. Due to the lack of available data, and as a conservative measure, effects to these hearing groups from high-frequency sonars would utilize the lowest threshold available for other hearing groups (a cumulative sound exposure level of 210 dB re 1 μPa^2-s), but effects would largely be analyzed qualitatively.

3.6.3.1.2.2 Impact Ranges for Sonar and Other Transducers

The following section provides ranges to specific effects from sonar and other transducers. Ranges are calculated using criteria from Table 3.6-4 and the Navy Acoustic Effects Model. Only ranges to TTS were predicted based on available data. Sonar durations of 1, 30, 60 and 120 seconds were used to calculate the ranges below. However, despite the variation in exposure duration, ranges were almost identical across these durations and therefore were combined and summarized by bin in the table below. General source levels, durations, and other characteristics of these systems are described in Section 3.0.3.3.1 (Acoustic Stressors).

Ranges to TTS for mid-frequency sonar bins are only estimated for fishes with a swim bladder involved in hearing and fishes with high-frequency hearing. The maximum range to TTS is up to 10 m for these most sensitive hearing groups, but only for the most powerful sonar bins (e.g., MF1).

Table 3.6-4: Ranges to Temporary Threshold Shift from Four Representative Sonar Bins

Fish Hearing Group	*Range to Effects (meters)*			
	Sonar Bin LF5 Low-frequency	*Sonar Bin MF1 Hull-mounted surface ship sonars (e.g., AN/SQS-53C and AN/SQS-61)*	*Sonar Bin MF4 Helicopter-deployed dipping sonars (e.g., AN/AQS-22)*	*Sonar Bin MF5 Active acoustic sonobuoys (e.g., DICASS)*
Fishes without a swim bladder	NR	NR	NR	NR
Fishes with a swim bladder not involved in hearing	0	NR	NR	NR
Fishes with a swim bladder involved in hearing	0	7 (5 – 10)	0	0
Fishes with a swim bladder and high frequency hearing	0	7 (5 – 10)	0	0

Notes: Ranges to TTS represent modeled predictions in different areas and seasons within the Study Area. The average range to TTS is provided as well as the minimum to the maximum range to TTS in parenthesis. Where only one number is provided the average, minimum, and maximum ranges to TTS are the same. NR = no criteria are available and therefore no range to effects are estimated.

3.6.3.1.2.3 Impacts from Sonar and Other Transducers Under Alternative 1

Impacts from Sonar and Other Transducers Under Alternative 1 for Training Activities

Sonar and other transducers emit sound waves into the water to detect objects, safely navigate, and communicate. Use of sonar and other transducers would typically be transient and temporary. General categories and characteristics of sonar systems and the number of hours these sonars would be operated during training under Alternative 1 are described in Section 3.0.3.3.1 (Acoustic Stressors). Activities using sonars and other transducers would be conducted as described in Chapter 2 (Description of Proposed Action and Alternatives) and Appendix A (Navy Activity Descriptions).

Under Alternative 1, the number of major training exercises, integrated/coordinated training activities, civilian port defense activities, and sinking exercises would fluctuate annually. In addition, a portion of anti-submarine warfare tracking exercise –ship unit-level training activities would be conducted synthetically or in conjunction with other training exercises. Training activities using sonar and other transducers could occur throughout the Study Area, although use would generally occur within 200 NM of shore in Navy Operating Areas, on Navy range complexes, on Navy testing ranges, or around inshore locations.

Only a few species of shad within the Clupeidae family, subfamily Alosinae, are known to be able to detect high-frequency sonar and other transducers (greater than 10 kHz) and are considered a part of the fish hearing group for species with a swim bladder that have high-frequency hearing. However, these species are not present in the HSTT Study Area. ESA-listed fishes that occur in the Study Area cannot detect high-frequency sonars or other transducers, and most other marine fishes would probably not detect these sounds and would not experience masking, physiological stress, or behavioral disturbance. It is possible that some reef or deep-sea fishes may be able to detect high-frequency sonars (based on anatomical features in the inner ears) and could experience behavioral reactions and masking during these events. However, mine warfare activities that utilize high-frequency sonars are typically limited in duration and geographic extent. Furthermore, sound from high-frequency systems may only be detectable above ambient noise regimes in these coastal habitats from within a few kilometers, due to lower source levels and higher frequencies that do not propagate as far as other sonars. Behavioral reactions and masking, if they occurred for some reef and deep sea fishes, are expected to be transient, and long-term consequences for populations would not be expected.

As discussed above, most marine fish species are not expected to detect sounds in the mid-frequency range (above a few kHz) of most operational sonars. The fish species that are known to detect mid-frequencies (i.e., those with swim bladders, including some sciaenids [drum], most clupeids [herring, shad], and potentially deep-water fish such as myctophids [lanternfish]) do not have their best sensitivities in the range of the operational sonars. Thus, fishes may only detect the most powerful systems, such as hull-mounted sonar, within a few kilometers; and most other, less powerful mid-frequency sonar systems, for a kilometer or less. Fishes with a swim bladder involved in hearing and with high-frequency hearing are more susceptible to hearing loss due to exposure to mid-frequency sonars. However, the maximum estimated range to TTS for these fish hearing groups is equal to or less than 10 m for only the most powerful sonar bins. Fishes within these hearing groups would have to be very close to the source and the source levels would have to be relatively high in order to experience this effect.

Most mid-frequency active sonars used in the Study Area would not have the potential to substantially mask key environmental sounds or produce sustained physiological stress or behavioral reactions due to the limited time of exposure resulting from the moving sound sources and variable duty cycles. However, it is important to note that some mid-frequency sonars have a high duty cycle or are operated continuously. This may increase the risk of masking, but only for important biological sounds that overlap with the frequency of the sonar being operated. Furthermore, although some species may be able to produce sound at higher frequencies (greater than 1 kHz), vocal marine fishes, such as sciaenids, largely communicate below the range of mid-frequency levels used by most sonars. Any such effects would be temporary and infrequent as a vessel operating mid-frequency sonar transits an area. As such, mid-frequency sonar use is unlikely to impact individuals. Long-term consequences for fish populations due to exposure to mid-frequency sonar and other transducers are not expected.

All marine fish species can likely detect low-frequency sonars and other transducers. However, low-frequency active sonar use is limited and most low-frequency active operations are typically conducted in deeper waters, usually beyond the continental shelf break. The majority of fish species, including those that are the most highly vocal, exist on the continental shelf and within nearshore, estuarine areas. However, some species may still be present where low-frequency sonar and other transducers are used. Most low-frequency sonar sources do not have a high enough source level to cause TTS, as shown in Table 3.6-4. Although highly unlikely, if TTS did occur, it may reduce the detection of biologically significant sounds but would likely recover within a few minutes to days.

The majority of fish species exposed to sonar and other transducers within near (tens of meters) to far (thousands of meters) distances of the source would be more likely to experience; mild physiological stress; brief periods of masking; behavioral reactions such as startle or avoidance responses, although risk would be low even close to the source; or no reaction. However, based on the information provided in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), the relative risk of these effects at any distance are expected to be low. Due to the transient nature of most sonar operations, overall effects would be localized and infrequent, only lasting a few seconds or minutes. Based on the low level and short duration of potential exposure to low-frequency sonar and other transducers, long-term consequences for fish populations are not expected.

As discussed previously in Section 3.6.2.1.3 (Hearing and Vocalization) and as shown in Figure 3.6-2, all ESA-listed fish species that occur in the Study Area are capable of detecting sound produced by low-frequency sonars and other transducers. Scalloped hammerhead sharks, giant manta ray and oceanic whitetip sharks do not have a swim bladder and generally are not sensitive to frequencies above 1 kHz. It is assumed that fishes without a swim bladder cannot detect high-frequency sonars and may only detect mid-frequency sources below 2 kHz, with high source levels, and within close proximity to the source (a few tens of meters). Although steelhead and gulf grouper have a swim bladder not involved in hearing and may be able to detect some mid-frequency sources up to 2 kHz, they are not particularly sensitive to these frequencies. Therefore, effects from sound produced by mid- and high-frequency sonars and other transducers are not expected for each ESA-listed species.

The Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, and gulf grouper may be exposed to low-frequency sonar or other transducers associated with training activities in the Southern California Range Complex but are not anticipated to occur in the Hawaii Range Complex. However, occurrence of scalloped hammerhead sharks in Southern California is limited due to their preference for warm water temperatures. Scalloped hammerhead sharks are transient and if they do occur in the Southern California Range Complex, it would only be during times of the year when water temperatures increase or during unusually warm years (e.g., El Nino). In addition, adult steelhead may be exposed for limited periods of time throughout the year in oceanic habitats, depending on seasonality and type of spawning migration (winter-run versus summer-run) back into rivers. Giant manta ray and oceanic whitetip shark may be exposed to low-frequency sonar or other transducers throughout the Study Area. In particular, adult giant manta rays are typically found offshore but occasionally visit coastal areas where upwelling occurs. Pups (juveniles) typically spend their first few years in nearshore shallow-water environments. However, Southern California is the northern edge of the giant manta rays' distribution therefore reducing the probability of exposures in the Southern California Range Complex. Oceanic whitetip sharks would most likely be exposed to sonar in offshore areas. Because low-frequency sonar is operated in deeper waters beyond the shelf break, there would be little overlap in habitat for steelhead and gulf grouper, further decreasing the risk of exposure to these sources.

Overall, impacts on ESA-listed species that encounter sonar or other transducers within their hearing range would be similar to those discussed above for impacts on fishes in general. As described above, most low-frequency sonar sources do not have a high enough source level to cause TTS and TTS would not be anticipated in fishes without a swim bladder. Although highly unlikely, if TTS did occur in fishes with a swim bladder, it may result in a reduction in detection of biologically significant sounds but would likely recover within a few minutes to days. ESA-listed species within the Study Area would be more likely to experience masking, physiological stress, and behavioral reactions, although risk would be low even close to the source. These impacts would be short-term (seconds to minutes) for individuals and long-term consequences for populations would not be expected. Multiple exposures for individuals within a short period (seconds to minutes) are unlikely due to the transient nature of most sonar activities. Although some shark species have shown attraction to irregularly pulsed low-frequency sounds (below several hundred Hz), they are not known to be attracted to continuous signals or higher frequencies that they presumably cannot hear (Casper & Mann, 2006; Casper & Mann, 2009; Casper et al., 2012a).

As discussed in Section 3.6.2.2 (Endangered Species Act-Listed Species), the designated physical and biological features (sites for spawning, sites for juvenile rearing, and sites for migration) for steelhead do not occur within the Study Area.

Pursuant to the ESA, the use of sonar and other transducers during training activities as described under Alternative 1 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from Sonar and Other Transducers Under Alternative 1 for Testing Activities

General categories and characteristics of sonar systems and the number of hours these sonars would be operated during testing under Alternative 1 are described in Section 3.0.3.3.1 (Acoustic Stressors). Activities using sonars and other transducers would be conducted as described in Chapter 2 (Description of Proposed Action and Alternatives) and Appendix A (Navy Activity Descriptions).

Under Alternative 1, the number of testing activities would fluctuate annually. Testing activities using sonar and other transducers could occur throughout the Study Area, although use would generally occur within Navy range complexes, on Navy testing ranges, or around inshore locations identified in Chapter 2 (Description of Proposed Action and Alternatives). Low-frequency sources are operated more frequently during testing activities than during training activities. Therefore, although the general impacts from sonar and other transducers during testing would be similar in severity to those described during training, there may be slightly more impacts during testing activities.

Hearing loss in fishes from exposure to sonar and other transducers is unlikely. Although unlikely, if TTS did occur, it would occur within tens of meters of the source and only in select hearing groups. The majority of fish species exposed to sonar and other transducers within near (tens of meters) to far (thousands of meters) distances of the source would be more likely to experience; mild physiological stress; brief periods of masking; behavioral reactions such as startle or avoidance responses, although risk would be low even close to the source; or no reaction. However, based on the information provided in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), the relative risk of these effects at any distance are expected to be low. Long-term consequences for individual fish are unlikely in most cases because acoustic exposures are intermittent, transient and unlikely to repeat over short periods. Since long-term consequences for most individuals are unlikely, long-term consequences for populations are not expected.

All ESA-listed fish species that occur in the Study Area have the potential to be exposed to sonar or other transducer use during testing activities, as activities involving these sources may occur in all range complexes, testing ranges, and at numerous inshore locations. The Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead and gulf grouper may be exposed to low-frequency sonar or other transducers associated with training activities in the Southern California Range Complex but are not anticipated to occur in the Hawaii Range Complex. However, occurrence of scalloped hammerhead sharks in Southern California is limited due to their preference for warm water temperatures. Scalloped hammerhead sharks are transient and if they do occur in the Southern California Range Complex, it would only be during times of the year when water temperatures increase or during unusually warm years (e.g., El Nino). In addition, adult steelhead may be exposed for limited periods of time throughout the year in oceanic habitats, depending on seasonality and type of spawning migration (winter-run versus summer-run) back into rivers. Giant manta ray and oceanic whitetip shark may be exposed to low-frequency sonar or other transducers throughout the Study Area. In particular, adult giant manta rays are typically found offshore but occasionally visit coastal areas where upwelling occurs. Pups (juveniles) typically spend their first few years in nearshore shallow-water environments. However, Southern California is the northern edge of the giant manta rays' distribution therefore reducing the probability of exposures in the Southern California Range Complex. Oceanic whitetip sharks would most likely be exposed to sonar in offshore areas.

As discussed above, all ESA-listed fish species that occur in the Study Area are capable of detecting sound produced by low-frequency sonars and other transducers but may only detect mid-frequency sources below 2 kHz, with high source levels, and within close proximity to the source (a few tens of meters). Therefore, effects from sound produced by mid- and high-frequency sonars and other transducers are not expected for any ESA-listed species.

Overall impacts on ESA-listed species that encounter sonar or other transducers within their hearing range would be similar to those discussed for other fishes that occur in the Study Area. TTS would not be anticipated in fishes without a swim bladder. Most low-frequency sonar sources do not have a high enough source level to cause TTS. Although highly unlikely, if TTS did occur in fishes with a swim bladder, it may result in a reduction in detection of biologically significant sounds but would likely recover within a few minutes to days. Most ESA-species within the Study Area could experience masking, physiological stress, and behavioral reactions; however, the relative risk of these occurring is low and these impacts would be short-term (seconds to minutes) for individuals. Multiple exposures for individuals within a short period (seconds to minutes) throughout most of the range complexes are unlikely due to the transient nature of sonar activities. Testing activities at pierside locations may increase the likelihood of repeated exposures. However, repeated exposures would only involve short-term (seconds to minutes) and minor behavioral impacts, which, repeated a few times per year, would still only lead to short-term (seconds to minutes) impacts for individuals and long-term consequences for populations would not be expected.

As discussed in Section 3.6.2.2 (Endangered Species Act-Listed Species) the designated physical and biological features (sites for spawning, sites for juvenile rearing, and sites for migration) for steelhead do not occur within the Study Area.

Pursuant to the ESA, the use of sonar and other transducers during testing activities as described under Alternative 1 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.1.2.4 Impacts from Sonar and Other Transducers Under Alternative 2

Impacts from Sonar and Other Transducers Under Alternative 2 for Training Activities

Sonar and other transducers emit sound waves into the water to detect objects, safely navigate, and communicate. Use of sonar and other transducers would typically be transient and temporary. General categories and characteristics of sonar systems, and the number of hours these sonars would be operated during training under Alternative 2 are described in Section 3.0.3.3.1 (Acoustic Stressors). Activities using sonars and other transducers would be conducted as described in Chapter 2 (Description of Proposed Action and Alternatives) and Appendix A (Navy Activity Descriptions).

Under Alternative 2, the maximum number of training activities could occur every year and all unit level training requirements would be completed at sea rather than synthetically. In addition, all unit level surface ship anti-submarine warfare training requirements would be completed through individual events conducted at sea, rather than through leveraging other anti-submarine warfare training exercises or the use of synthetic trainers. This would result in an increase of sonar use compared to Alternative 1. Training activities using sonar and other transducers could occur throughout the Study Area.

Impacts on fishes due to sonar and other transducers are expected to be limited to minor behavioral responses, short-term physiological stress, and brief periods of masking (seconds to minutes at most) for individuals; long-term consequences for individuals and therefore populations would not be expected. Predicted impacts on ESA-listed fish species and designated critical habitat would not be discernible from those described above in Section 3.6.3.1.2.3 (Impacts from Sonar and Other Transducers under Alternative 1 for Training Activities).

Pursuant to the ESA, the use of sonar and other transducers during training activities as described under Alternative 2 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks.

Impacts from Sonar and Other Transducers Under Alternative 2 for Testing Activities

General categories and characteristics of sonar systems and the number of hours these sonars would be operated during testing under Alternative 2 are described in Section 3.0.3.3.1 (Acoustic Stressors). Activities using sonars and other transducers would be conducted as described in Chapter 2 (Description of Proposed Action and Alternatives) and Appendix A (Navy Activity Descriptions).

Under Alternative 2, the maximum number of nearly all testing activities would occur every year. This would result in an increase of sonar use compared to Alternative 1. Testing activities using sonar and other transducers could occur throughout the Study Area, although use would generally occur within Navy range complexes, on Navy testing ranges, or around inshore locations identified in Chapter 2 (Description of Proposed Action and Alternatives).

Impacts on fishes due to sonar and other transducers are expected to be limited to minor behavioral responses, short-term physiological stress, and brief periods of masking (seconds to minutes) for individuals; long-term consequences for individuals and therefore populations would not be expected. Predicted impacts on ESA-listed fish species and designated critical habitat would not be discernible from those described above in Section 3.6.3.1.2.3 (Impacts from Sonar and Other Transducers Under Alternative 1 for Testing Activities).

Pursuant to the ESA, the use of sonar and other transducers during testing activities as described under Alternative 2 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks.

3.6.3.1.2.5 Impacts from Sonar and Other Transducers Under the No Action Alternative

Impacts from Sonar and Other Transducers Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various acoustic stressors (e.g., sonar and other transducers) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment either would remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.1.3 Impacts from Air Guns

Fishes could be exposed to sounds from air guns during testing activities. General categories and characteristics of air guns and the number of hours these air guns will be operated are described in Section 3.0.3.3 (Identifying Stressors for Analysis). The activities analyzed in the EIS/OEIS that use air guns are also described in Appendix A (Navy Activity Descriptions).

As discussed in Section 3.6.2.1.3 (Hearing and Vocalization), most marine fish species hear primarily below 1 kHz. Fish species within each of the four fish hearing groups would likely be able to detect sounds produced by air guns. Exposure of fishes to air guns activities could result in direct injury, hearing loss, masking, physiological stress, or behavioral reactions.

3.6.3.1.3.1 Methods for Analyzing Impacts from Air Guns

The Navy performed a quantitative analysis to estimate ranges to effect for fishes exposed to air guns during Navy testing activities. Inputs to the quantitative analysis included sound propagation modeling in the Navy's Acoustic Effects Model and sound exposure criteria and thresholds presented below. Although ranges to effects are predicted, density data for fish species within the Study Area are not available; therefore, it is not possible to estimate the total number of individuals that may be affected by sound produced by air guns.

Criteria and Thresholds Used to Estimate Impacts from Air Guns

Mortality and Injury from Air Guns

Criteria and thresholds to estimate impacts from sound produced by air gun activities are presented below in Table 3.6-5. Consistent with the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), dual metric sound exposure criteria are utilized to estimate mortality and injury from exposure to air guns. For purposes of this analysis, it is assumed that a specified effect will occur when either metric (cumulative sound exposure level or peak sound pressure level) is met or exceeded. Due to the lack of detailed data on injury thresholds in fishes exposed to air guns, thresholds from impact pile driving exposures are used as a proxy for this analysis (Halvorsen et al., 2011; Halvorsen et al., 2012a; Halvorsen et al., 2012b). General research findings regarding mortality and injury in fishes are discussed under Section 3.6.3.1.1.1 (Injury due to Impulsive Sound Sources).

Table 3.6-5: Sound Exposure Criteria for Mortality and Injury from Air Guns

Fish Hearing Group	Onset of Mortality		Onset of Injury	
	SEL_{cum}	SPL_{peak}	SEL_{cum}	SPL_{peak}
Fishes without a swim bladder	> 219	> 213	> 216	> 213
Fishes with a swim bladder not involved in hearing	210	> 207	203	> 207
Fishes with a swim bladder involved in hearing	207	> 207	203	> 207
Fishes with a swim bladder and high-frequency hearing	207	> 207	203	> 207

Notes: SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micropascal squared seconds [dB re 1 μPa^2-s]), SPL_{peak} = Peak sound pressure level (decibel referenced to 1 micropascal [dB re 1 μPa]), “>” indicates that the given effect would occur above the reported threshold.

As discussed under Section 3.6.3.1.1.1 (Injury due to Impulsive Sound Sources), injury and mortality in fishes exposed to impulsive sources may vary depending on the presence or absence of, and type of swim bladder. Injury and mortal injury has not been observed in fishes without a swim bladder because of exposure to impulsive sources (Halvorsen et al., 2011; Halvorsen et al., 2012a). Therefore, these effects would likely occur above the given thresholds in Table 3.6-5. Cumulative sound exposure thresholds for mortality and injury in fishes with a swim bladder were measured by investigators (Halvorsen et al., 2011; Halvorsen et al., 2012a; Halvorsen et al., 2012b). However, only the single strike peak sound pressure level was measured during these experiments; therefore, mortality and injury thresholds are assumed to be the same across all hearing groups with a swim bladder (Popper et al., 2014).

Hearing Loss from Air Guns

Criteria and thresholds to estimate TTS in fishes exposed to sound produced by air guns are presented below in Table 3.6-6 and are consistent with the thresholds presented in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014). General research findings regarding hearing loss in fishes are discussed under Section 3.6.3.1.1.2 (Hearing Loss due to Impulsive Sound Sources).

As discussed in Section 3.6.3.1.1.2 (Hearing Loss), exposure to sound produced from an air gun at a cumulative sound exposure level of 186 dB re 1 μPa^2-s has resulted in TTS in fishes (Popper et al., 2005). TTS is not likely to occur in fishes without a swim bladder and would likely occur above the given threshold in Table 3.6-5 for fishes with a swim bladder not involved in hearing.

Table 3.6-6: Sound Exposure Criteria for TTS from Air Guns

Fish Hearing Group	*TTS (SEL_{cum})*
Fishes without a swim bladder	NC
Fishes with a swim bladder not involved in hearing	> 186
Fishes with a swim bladder involved in hearing	186
Fishes with a swim bladder and high-frequency hearing	186

Notes: TTS = Temporary Threshold Shift, SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micropascal squared seconds [dB re 1 μPa^2-s]), NC = effects from exposure to sound produced by air guns is considered to be unlikely, therefore no criteria are reported, ">" indicates that the given effect would occur above the reported threshold.

3.6.3.1.3.2 Impact Ranges for Air Guns

The following section provides range to effects for fishes exposed to air gun activities. Air gun activities occur offshore and involve the use of a single shot or 10 shots. The following ranges are based on the Sound Exposure Level metrics for PTS and TTS for 10 firing of an air gun, a conservative estimate of the number of air gun firings that could occur over a single exposure duration at a single location. Table 3.6-7 presents the approximate ranges in meters to mortality, onset of injury and TTS. Ranges to effect for each hearing group may vary depending on the available criteria or other factors such as location of the activity, season the activity occurs, or depth of the activity.

Mortality or injury could occur in all fishes with a swim bladder from exposure to air guns within or less than a maximum of 14 m. These effects could occur in fishes without a swim bladder out to distance less than of 7 m from the source. Hearing loss may occur in fishes with a swim bladder from exposure to air gun activities out to an average of 12 m or less, depending on the hearing group. In some cases, these effects may occur out to a maximum of 30 m. Hearing loss is not anticipated to occur in fishes without a swim bladder. The probability of these effects would decrease with increasing distance from the pile.

3.6.3.1.3.3 Impacts from Air Guns Under Alternative 1

Impacts from Air Guns Under Alternative 1 for Training Activities

Training activities under Alternative 1 do not include the use of air guns.

Impacts from Air Guns Under Alternative 1 for Testing Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Section 3.0.3.3 (Identifying Stressors for Analysis) and Appendix A (Navy Activity Descriptions), testing activities under Alternative 1 would include the use of single air guns in the Southern California and Hawaii Range complexes.

Table 3.6-7: Range to Effect for Fishes Exposed to 10 Air Gun Shots

Fish Hearing Group	Range to Effects (meters)[1]				
	Onset of Mortality		Onset of Injury		TTS
	SEL_{cum}	SPL_{peak}	SEL_{cum}	SPL_{peak}	SEL_{cum}
Fishes without a swim bladder	0	< 5 (4–7)	0 (0–0)	< 5 (4–7)	NR
Fishes with a swim bladder not involved in hearing	0	< 10 (8–14)	10 (8–14)	< 10 (8–14)	< 12 (4–30)
Fishes with a swim bladder involved in hearing	0 (0–2)	< 10 (8–14)	10 (8–14)	< 10 (8–14)	12 (4–30)
Fishes with a swim bladder and high-frequency hearing	0 (0–2)	< 10 (8–14)	10 (8–14)	< 10 (8–14)	12 (4–30)

[1] Range to effects represent modeled predictions in different areas and seasons within the Study Area. Each cell contains the estimated average, minimum and maximum range to the specified effect.
Notes: SEL_{cum} = Cumulative sound exposure level, SPL_{peak} = Peak sound pressure level, TTS = Temporary Threshold Shift, NR = no criteria are available and therefore no range to effects are estimated, "<" indicates that the given effect would occur at distances less than the reported range(s).

Impulses from air guns lack the strong shock wave and rapid pressure increases known to cause primary blast injury or barotrauma during explosive events and (to a lesser degree) impact pile driving. Although data from impact pile driving are often used as a proxy to estimate effects to fish from air guns, this may be an overly conservative metric due to the differences in rise times between the two types of impulsive sources. Typically, impact pile driving signals have a much steeper rise time and higher peak pressure than air gun signals. While mortality, injury, or TTS may occur at the individual level because of air gun activities, considering the small estimated footprint of the mortality/injury zone (Table 3.6-7) and the isolated and infrequent use of air guns, population-level consequences would not be expected.

Air guns produce broadband sounds; however, the duration of an individual impulse is about 1/10th of a second. Masking could potentially occur as a result of exposure to sound produced by air guns. However, due to the brief nature of each pulse, it is unlikely that fishes within relatively close distance of the source (tens to hundreds of meters) experience these effects. It is more likely that masking would occur at farther distances from the source where signals may appear continuous. This may result in brief periods where fishes are unable to detect vocalizations from other fish and predators. Fishes may also respond by altering their vocalizations to compensate for the noise. However, these effects would only occur if air gun signals are detectable over the existing ambient noise.

In addition, fish that are able to detect the air gun impulses may exhibit signs of physiological stress or alterations in natural behavior. Some fish species with site fidelity such as reef fish may show initial startle reactions, returning to normal behavioral patterns within a matter of a few minutes. Pelagic and schooling fish that typically show less site fidelity may avoid the immediate area for the duration of the events. Multiple exposures to individuals (across days) are unlikely as air guns are not operated in the same areas from day to day, but rather would be utilized in different areas over time. Due to the limited use and relatively small footprint of air guns, impacts on fish are expected to be minor. Population consequences would not be expected.

As discussed previously in Section 3.6.2.1.3 (Hearing and Vocalization), all ESA-listed fish species that occur in the Study Area are capable of detecting sound produced by air guns. Scalloped hammerhead sharks, steelhead and gulf grouper could be exposed to sound from air guns associated with testing activities in the offshore areas of the Southern California Range Complex. However, exposures would be extremely rare as scalloped hammerhead shark would only likely occur in the Study Area during unusually warm years and steelhead are only present in oceanic habitats seasonally, depending on spawning migration (winter-run versus summer-run) back into rivers. Giant manta ray and oceanic whitetip shark may be exposed to air guns in offshore areas throughout the Study Area.

Overall, impacts on ESA-listed species that encounter air gun activities would be similar to those discussed for other fishes that occur in the Study Area. ESA-listed fishes could potentially suffer mortality or injury, with the probability and severity increasing closer to the air gun. Although there are estimated ranges to mortality and injury, on average, these ranges are relatively short (less than 10 m) across all fish hearing groups, further reducing the likelihood that mortality or injury would occur due to exposure to air gun activities. It is more likely that ESA-listed fishes that are exposed to air gun activities would result in behavioral reactions or physiological stress depending on their proximity to the activity. As described in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), masking effects within hundreds of meters from the source would be highly unlikely due to the short duration of the signal pulse.

As discussed in Section 3.6.2.2 (Endangered Species Act-Listed Species) the designated physical and biological features (sites for spawning, sites for juvenile rearing, and sites for migration) for steelhead do not occur within the Study Area.

Pursuant to the ESA, the use of air guns during testing activities as described under Alternative 1 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.1.3.4 Impacts from Air Guns Under Alternative 2

Impacts from Air Guns Under Alternative 2 for Training Activities

Training activities under Alternative 2 do not include the use of air guns.

Impacts from Air Guns Under Alternative 2 for Testing Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Section 3.0.3.3 (Identifying Stressors for Analysis) and Appendix A (Navy Activity Descriptions), testing activities under Alternative 2 would include activities that produce in-water noise from the use of air guns. Testing activities under Alternative 2 would be identical to those described under Alternative 1; therefore, the locations, types, and severity of predicted impacts would be identical to those described above in Section 3.6.3.1.3.3 (Impacts from Air Guns Under Alternative 1).

Pursuant to the ESA, the use of air guns during testing activities as described under Alternative 2 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks.

3.6.3.1.3.5 Impacts from Air Guns Under the No Action Alternative

Impacts from Air Guns Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various acoustic stressors (e.g., air guns) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment either would remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.1.4 Impacts from Pile Driving

Fishes could be exposed to sounds produced by impact pile driving and vibratory pile extraction activities during the construction and removal phases of the Elevated Causeway System described in Chapter 2 (Description of Proposed Action and Alternatives), and Appendix A (Navy Activity Descriptions). The training involves the use of an impact hammer to drive the 24-inch steel piles into the sediment and a vibratory hammer to later remove the piles that support the causeway structure. The impulses can produce a shock wave that is transmitted to the sediment and water column (Reinhall & Dahl, 2011). Elevated Causeway System pile installation and removal within the project area would result in a short-term increase in underwater noise levels (approximately one month out of a year). Section 3.0.3.3.1.3 (Pile Driving) provides additional details on pile driving and noise levels measured from similar operations. Pile driving activities produce broadband sound, therefore it is anticipated that all fishes within each fish hearing group discussed in Section 3.6.2.1.3 (Hearing and Vocalization) would likely be able to detect sound produced by impact pile driving and vibratory pile extraction activities. Exposure of fishes to pile driving activities could result in direct injury, hearing loss, masking, physiological stress, or behavioral reactions.

3.6.3.1.4.1 Methods for Analyzing Impacts from Pile Driving

The Navy performed a quantitative analysis to estimate the range to effect for fishes exposed to impact pile driving during Navy training activities. Inputs to the quantitative analysis included basic sound propagation modeling and sound exposure criteria and thresholds presented below. Although ranges to effect are predicted, density data for fish species within the Study Area are not available, therefore it is not possible to estimate the total number of individuals that may be affected by sound produced by impact pile driving.

Currently, there are no proposed criteria for vibratory pile extraction activities, and therefore these activities are analyzed based on available literature and other observed reactions.

Criteria and Thresholds Used to Estimate Impacts from Pile Driving

Mortality and Injury from Pile Driving

Criteria and thresholds to estimate impacts from sound produced by impact pile driving activities are presented below in Table 3.6-8. Consistent with the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), dual metric sound exposure criteria are utilized to estimate mortality and injury from exposure to impact pile driving. For purposes of this analysis, it is assumed that a specified effect will occur when either metric (cumulative sound exposure level or peak sound pressure level) is met or exceeded. General research findings regarding mortality and injury in fishes as well as findings specific to exposure to other impulsive sound sources are discussed under Section 3.6.3.1.1.1 (Injury due to Impulsive Sound Sources).

Table 3.6-8: Sound Exposure Criteria for Mortality and Injury from Impact Pile Driving

Fish Hearing Group	*Onset of Mortality*		*Onset of Injury*	
	SEL_{cum}	*SPL_{peak}*	*SEL_{cum}*	*SPL_{peak}*
Fishes without a swim bladder	> 219	> 213	> 216	> 213
Fishes with a swim bladder not involved in hearing	210	> 207	203	> 207
Fishes with a swim bladder involved in hearing	207	> 207	203	> 207
Fishes with a swim bladder and high-frequency hearing	207	> 207	203	> 207

Notes: SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micropascal squared seconds [dB re 1 μPa^2-s]), SPL_{peak} = Peak sound pressure level (decibel referenced to 1 micropascal [dB re 1 μPa]), “>” indicates that the given effect would occur above the reported threshold.

An explanation of mortality and injury criteria are also available under Section 3.6.3.1.3.1 (Methods for Analyzing Impacts from Air Guns).

Hearing Loss from Pile Driving

Criteria and thresholds to estimate TTS in fishes exposed to sound produced by impact pile driving activities are presented below in Table 3.6-9. Sound exposure thresholds are available in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014) and inform the TTS thresholds presented here. Due to the lack of data on hearing loss in fishes exposed to impact pile driving, data from air gun studies were used as a proxy for this analysis (Popper et al., 2005). General research findings regarding hearing loss in fishes are discussed under Section 3.6.3.1.1.2 (Hearing Loss due to Impulsive Sound Sources).

An explanation of hearing loss criteria is also available under Section 3.6.3.1.3.1 (Methods for Analyzing Impacts from Air Guns).

Table 3.6-9: Sound Exposure Criteria for TTS from Impact Pile Driving

Fish Hearing Group	*TTS (SEL_{cum})*
Fishes without a swim bladder	NC
Fishes with a swim bladder not involved in hearing	> 186
Fishes with a swim bladder involved in hearing	186
Fishes with a swim bladder and high-frequency hearing	186

Notes: TTS = Temporary Threshold Shift, SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micropascal squared seconds [dB re 1 μPa^2-s]), NC = effects from exposure to sound produced by impact pile driving is considered to be unlikely, therefore no criteria are reported, > indicates that the given effect would occur above the reported threshold.

Modeling of Pile Driving Noise

Underwater noise effects from pile driving and vibratory pile extraction were modeled using actual measures of impact pile driving and vibratory removal during construction of an elevated causeway (Illingworth and Rodkin, 2015, 2017). A conservative estimate of spreading loss of sound in shallow coastal waters (i.e., transmission loss = 16.5*Log10[radius]) was applied based on spreading loss observed in actual measurements. Inputs used in the model are provided in Section 3.0.3.3.1.3 (Pile Driving), including source levels; the number of strikes required to drive a pile and the duration of vibratory removal per pile; the number of piles driven or removed per day; and the number of days of pile driving and removal.

3.6.3.1.4.2 Impact Ranges for Pile Driving

The following section provides range to effects for fishes exposed to impact pile driving to specific criteria determined using the calculations and modeling described above. Fishes within these ranges would be predicted to receive the associated effect. Where effects are anticipated to occur above the designated criteria (see Table 3.6-10), the estimated ranges to that effect would be less than those displayed in the table.

Because of the static nature of pile driving activities, two different exposure times were used when calculating ranges to effect for different types of fish (e.g., transient species vs. species with high site fidelity). It is assumed that some transient fishes (e.g., pelagic species) would likely move through the area during pile driving activities, resulting in less time exposed. Therefore, ranges to effect for these species are estimated based on 35 strikes per minute, for a cumulative exposure time of one minute (see Table 3.6-10). In addition, it is assumed that ranges to mortality or injury would actually be less than the ranges shown in the table due to the criteria that informed the range calculations.

Table 3.6-10: Impact Ranges for Transient Fishes from Impact Pile Driving for 35 Strikes (1 minute)

Fish Hearing Group	*Range to Effects (meters)*				
	Onset of Mortality		*Onset of Injury*		*TTS*
	SEL_{cum}	SPL_{peak}	SEL_{cum}	SPL_{peak}	SEL_{cum}
Fishes without a swim bladder	< 1	< 8	< 1	< 8	NR
Fishes with a swim bladder not involved in hearing	2	< 17	5	< 17	< 57
Fishes with a swim bladder involved in hearing	3	< 17	5	< 17	57
Fishes with a swim bladder and high-frequency hearing	3	< 17	5	< 17	57

Notes: SEL_{cum} = Cumulative sound exposure level, SPL_{peak} = Peak sound pressure level, TTS = Temporary Threshold Shift, NR = no criteria are available and therefore no range to effects are estimated, "<" indicates that the given effect would occur at distances less than the reported range(s).

Based on the measured sound levels for pile driving, mortality or injury could occur in transient or pelagic fishes with a swim bladder from exposure to impact pile driving at a distance less than 17 m from the source. In addition, it is assumed that these fishes may also experience signs of hearing loss out to a distance of, or less than, 57 m depending on the fish hearing group. The probability of these effects would decrease with increasing distance from the pile. Fishes without a swim bladder would not likely experience TTS and would only have the potential for mortality or injury effects at a distance less than 8 m of the source.

In contrast, it is assumed that fish with high site fidelity (e.g., demersal or reef fish) may stay in the area during pile driving activities and therefore may receive a longer exposure. As a conservative measure, ranges in Table 3.6-11 were calculated based on an estimated 3,150 strikes over the course of an entire day.

Under the assumption that fish are stationary and remain in the area for the duration of a full day of pile driving activities, mortality and injury could occur from exposure to impact pile driving within a maximum distance of 46 m and potentially out to 81 m from the source, respectively, for species within the most sensitive hearing groups (i.e., fishes with a swim bladder involved in hearing and fishes with high-frequency hearing). In addition, fishes with a swim bladder may also experience signs of hearing loss out to 868 m. The probability of these effects would decrease with increasing distance from the pile. Fishes without a swim bladder would not likely experience TTS and would only have the potential for mortality or injury effects within 9 or 13 m of the source, respectively.

Table 3.6-11: Impact Ranges for Fishes with High Site Fidelity from Impact Pile Driving for 3,150 strikes (1 Day)

Fish Hearing Group	*Range to Effects (meters)*				
	Onset of Mortality		*Onset of Injury*		*TTS*
	SEL_{cum}	*SPL_{peak}*	*SEL_{cum}*	*SPL_{peak}*	*SEL_{cum}*
Fishes without a swim bladder	< 9	< 8	< 13	< 8	NR
Fishes with a swim bladder not involved in hearing	30	< 17	81	< 17	< 868
Fishes with a swim bladder involved in hearing	46	< 17	81	< 17	868
Fishes with a swim bladder and high-frequency hearing	46	< 17	81	< 17	868

Notes: SEL_{cum} = Cumulative sound exposure level, SPL_{peak} = Peak sound pressure level, TTS = Temporary Threshold Shift, NR = no criteria are available and therefore no range to effects are estimated, "<" indicates that the given effect would occur at distances less than the reported range(s).

3.6.3.1.4.3 Impacts from Pile Driving Under Alternative 1

Impacts from Pile Driving Under Alternative 1 for Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Table 2.6-1, Section 3.0.3.3 (Identifying Stressors for Analysis), and Appendix A (Navy Activity Descriptions), training activities under Alternative 1 include pile driving associated with construction and removal of the elevated causeway system. This activity would take place nearshore and within the surf zone for up to 30 days (20 days for construction and 10 days for removal). Specifically, pile driving activities would only occur twice per year, either at Silver Strand Training Complex, California, or at Marine Corps Base Camp Pendleton, California. The pile driving locations are within coastal areas that tend to have high ambient noise levels due to natural and anthropogenic sources.

Impulses from the impact hammer are broadband and carry most of their energy in the lower frequencies. The impulses are within the hearing range of all fish, and in close proximity exhibit an overpressure shock front in the water due to the high-speed travel of the impact pressure wave down and back up the steel pile (Reinhall & Dahl, 2011). The impulse can also travel through the bottom sediment. Fishes may be exposed to sound or energy from impact and vibratory pile driving associated with training activities throughout the year.

Range to effects for fishes with high site fidelity are generally longer than those reported for transient fishes due to the differences in cumulative exposure time (see Table 3.6-10 and Table 3.6-11). However, it is not likely that either type of fish would remain close enough to a pile driving source for an entire day or long enough to result in mortality or injury. In some cases, based on behavioral response data to impulsive sources, as described in Section 3.6.3.1.1.5 (Behavioral Reactions), individuals that do startle or avoid the immediate area surrounding a pile driving activity would likely habituate and return to normal behaviors after initial exposure. Signs of hearing loss however may occur in fishes exposed to initial pile driving activities. Fishes that experience hearing loss may have reduced ability to detect biologically important sounds until their hearing recovers. Recovery from hearing loss begins almost immediately after the noise exposure ceases and can take a few minutes to a few days to fully recover, depending on the magnitude of the initial threshold shift. As discussed in Section 2.3.3.13 (Pile Driving Safety), as a standard operating procedure, the Navy performs soft starts at reduced energy during an initial set of strikes from an impact hammer. Soft starts may “warn” fish and cause them to move away from the sound source before impact pile driving increases to full operating capacity. Considering the small footprint of this injury zone and standard operating procedure for soft starts, long-term consequences to transient individuals, and therefore population consequences, would not be expected. Fishes with high site fidelity would be at more risk to experience effects from impact pile driving, but these effects would also not be likely to result in population level consequences.

Fishes exposed to vibratory extraction would not likely result in mortality, injury, or TTS based on the low source level and limited duration of these activities as discussed in Section 3.0.3.3.1.3 (Pile Driving). Based on the predicted impact pile driving and vibratory extraction noise levels, fishes may also exhibit other responses such as masking, physiological stress, or behavioral responses. Masking only occurs when the interfering signal is present; however, impact pile driving activities are intermittent. Therefore, masking would be localized and of limited duration during impact pile driving. Fishes may habituate, or choose to tolerate pile driving sound after multiple strikes, returning to normal behavior patterns during the pile driving activities. Vibratory pile extraction is more likely than impact pile driving to cause masking of environmental sounds; however, due to its low source level, the masking effect would only be relevant in a small area around the vibratory pile extraction activity. Fishes may also react to pile driving and vibratory pile extraction sound by increasing their swimming speed, moving away from the source, or not responding at all.

As discussed previously (Section 3.6.2.1.3, Hearing and Vocalization), all ESA-listed fish species that occur in the Study Area are capable of detecting sound produced by pile driving activities. Scalloped hammerhead shark, steelhead, and giant manta rays could be exposed to pile driving activities in the Southern California Range Complex. However, exposures would be extremely rare as scalloped hammerhead shark would only likely occur in the Study Area during unusually warm years and steelhead are only present in oceanic habitats seasonally, depending on spawning migration (winter-run versus summer-run) back into rivers. Adult giant manta rays are typically found offshore but occasionally visit coastal areas where upwelling occurs, and pups (juveniles) typically spend their first few years in nearshore shallow-water environments. Southern California is the northern edge of the giant manta rays' distribution; therefore, exposure to sounds from pile driving or extraction to juveniles or adults would be limited to those few individuals found nearshore and on the outer edges of their habitat range. Habitat for oceanic whitetip sharks do not overlap areas where pile driving activities could occur.

Scalloped hammerhead sharks, steelhead, and giant manta rays could potentially suffer mortality, injury, or hearing loss with the probability and severity increasing closer to the pile driving activity. However, exposure is considered rare due to the limited overlap between habitat and activity area, and it is unlikely that exposed individuals would move closer to the source after initial exposure, nor would they remain within these zones for an entire day. Masking, physiological stress or behavioral reactions are also possible due to pile driving or vibratory pile extraction. Scalloped hammerhead shark, steelhead, and giant manta rays, that are exposed may habituate, or choose to tolerate pile driving sound after multiple strikes or vibratory extraction after multiple pile removals, returning to normal behavior patterns during the pile driving activities. Although individuals may be affected, long-term consequences for populations would not be expected.

As discussed in Section 3.6.2.2.2.1 (Status and Management) the majority of the designated physical and biological features (sites for spawning, sites for juvenile rearing, and sites for migration) for steelhead critical habitat occur in freshwater and estuaries, and do not overlap areas where pile driving activities will occur. Therefore, the proposed training activities would not affect the critical habitat.

Pursuant to the ESA, pile driving during training activities as described under Alternative 1 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper or oceanic whitetip sharks, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, and giant manta rays. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from Pile Driving Under Alternative 1 for Testing Activities

Pile driving (impact and vibratory) would not occur during testing activities under Alternative 1.

3.6.3.1.4.4 Impacts from Pile Driving Under Alternative 2

Impacts from Pile Driving Under Alternative 2 for Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Section 3.0.3.3 (Identifying Stressors for Analysis), and Appendix A (Navy Activity Descriptions), training activities under Alternative 2 include activities that produce in-water noise from the pile driving. Training activities under Alternative 2 would be identical to those described under Alternative 1; therefore, the locations, types, and severity of predicted impacts would be identical to those described above in Section 3.6.3.1.4.3 (Impacts from Pile Driving Under Alternative 1 for Training Activities).

Pursuant to the ESA, pile driving during training activities as described under Alternative 2 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper or oceanic whitetip sharks, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, and giant manta rays.

Impacts from Pile Driving Under Alternative 2 for Testing Activities

Pile driving (impact and vibratory) would not occur during testing activities under Alternative 2.

3.6.3.1.4.5 Impacts from Pile Driving Under the No Action Alternative

Impacts from Pile Driving Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various acoustic stressors (e.g., impact pile driving and vibratory pile extraction) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment either would remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.1.5 Impacts from Vessel Noise

Fishes may be exposed to sound from vessel movement. A detailed description of the acoustic characteristics and typical sound produced by vessels is in Section 3.0.3.3 (Identifying Stressors for Analysis). Vessel movements involve transits to and from ports to various locations within the Study Area. Many ongoing and proposed training and testing activities within the Study Area involve maneuvers by various types of surface ships, boats, and submarines (collectively referred to as vessels), as well as unmanned vehicles. Moderate- to low-level passive sound sources, including vessel noise, would not likely cause any direct injury or trauma due to characteristics of the sounds and the moderate source levels as discussed in Section 3.0.3.3.1 (Acoustic Stressors). Furthermore, although hearing loss because of continuous noise exposure has occurred, vessels are transient and would result in only brief periods of exposure. Injury and hearing loss because of exposure to vessel noise is not discussed further in this analysis.

As discussed in Section 3.6.2.1.3 (Hearing and Vocalization), all fish species should be able to detect vessel noise due to its low-frequency content and their hearing capabilities. Exposure to vessel noise could result in short-term behavioral or physiological responses (e.g., avoidance, stress) as discussed in Section 3.6.3.1.1.3 (Masking), Section 3.6.3.1.1.4 (Physiological Stress), and Section 3.6.3.1.1.5 (Behavioral Reactions).

Training and testing events involving vessel movements occur intermittently and range in duration from a few hours up to a few weeks. These activities are widely dispersed throughout the Study Area. The exception is for pierside activities, although these areas are located inshore, these are industrialized areas that are already exposed to high levels of anthropogenic noise due to numerous waterfront users (e.g., commercial properties, ports, marinas). Ships would produce low-frequency, broadband underwater sound below 1 kHz while smaller vessels would emit higher-frequency sound between 1 kHz to 50 kHz, though the exact level of sound produced varies by vessel type. Navy vessels make up a very small percentage of the overall traffic (Mintz, 2012), and the rise of ambient noise levels in the Study Area is a problem related to all ocean users, including commercial and recreational vessels and shoreline development and industrialization. Fishes could be exposed to a range of impacts depending on the source of vessel noise and context of the exposure. Specifically, impacts from exposure to vessel noise may include temporary hearing loss, auditory masking, physiological stress, or changes in behavior.

3.6.3.1.5.1 Methods for Analyzing Impacts from Vessel Noise

The impacts on fishes due to exposure to vessel noise are analyzed qualitatively by comparing reported observations under specific conditions as discussed in Section 3.6.3.1.1 (Background) to the conditions which fishes may be exposed to during proposed Navy activities.

3.6.3.1.5.2 Impacts from Vessel Noise Under Alternative 1

Impacts from Vessel Noise Under Alternative 1 for Training Activities

As discussed in Chapter 2 (Description of Proposed Action and Alternatives) and Section 3.0.3.3.1.4 (Vessel Noise), training activities under Alternative 1 include vessel movement in many events. Navy vessel traffic could occur anywhere within the Study Area, but would be concentrated near Navy ports such as San Diego and Pearl Harbor, and the HSTT Transit Corridor, which are heavily trafficked by private and commercial vessels, in addition to naval vessels. Navy ships make up only 8 percent of total ship traffic in Hawaii, and only 4 percent of total ship traffic in Southern California (Mintz, 2016). In terms of anthropogenic noise, Navy ships would contribute a correspondingly smaller amount of shipping noise compared to more common commercial shipping and boating (Mintz & Filadelfo, 2011; Mintz, 2012).

As described in Section 3.6.2.1.3 (Hearing and Vocalization), an increase in background noise levels from training and testing activities have the potential to expose fishes to sound and general disturbance, potentially resulting in short-term physiological stress, masking, or behavioral reactions. Fishes are more likely to react to nearby vessel noise (i.e., within tens of meters) than to vessel noise emanating from a distance. Fishes may have physiological stress reactions to sounds they can hear but typically, responses would be brief and would not affect the overall fitness of the animal. Auditory masking due to vessel noise can potentially mask vocalizations and other biologically important sounds (e.g., sounds of prey or predators) that fish may rely on. The low-frequency sounds of large vessels or accelerating small vessels can cause avoidance responses by fishes. However, impacts from vessel noise would be temporary and localized, and such responses would not be expected to compromise the general health or condition of individual fish. Therefore, long-term consequences for populations are not expected.

All ESA-listed species that occur in the Study Area are likely capable of detecting vessel noise as discussed previously in Section 3.6.2.1.3 (Hearing and Vocalization). Scalloped hammerhead sharks, steelhead, gulf grouper, may be exposed to vessel noise associated with training activities throughout the year in the Southern California Range Complex. Giant manta rays and oceanic whitetip sharks may be exposed throughout the Study Area. If exposure to vessel noise did occur, ESA-listed species could experience behavioral reactions, physiological stress, and masking, although these impacts would be expected to be short-term and infrequent based on the low probability of co-occurrence between vessel activity and species. Long-term consequences for populations would not be expected.

As discussed in the Section 3.6.2.2.2.1 (Status and Management) the majority of the designated physical and biological features (sites for spawning, sites for juvenile rearing, and sites for migration) for steelhead critical habitat occur in freshwater and estuaries, and do not occur within the offshore marine habitats of the Study Area.

Pursuant to the ESA, vessel noise during training activities as described under Alternative 1 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from Vessel Noise Under Alternative 1 for Testing Activities

As discussed in Chapter 2 (Description of the Proposed Action and Alternatives) and Section 3.0.3.3.1.4 (Vessel Noise), proposed testing activities under Alternative 1 include vessel movements in many events. Testing activities within the Study Area typically consist of a single vessel involved in unit-level activity for a few hours, one or two small boats conducting testing, or during a larger training event. Navy vessel traffic could occur anywhere within the Study Area, but would be concentrated near Navy ports such as San Diego and Pearl Harbor, which are heavily trafficked by private and commercial vessels, in addition to naval vessels. Navy ships make up only 8 percent of total ship traffic in Hawaii, and only 4 percent of total ship traffic in Southern California (Mintz, 2016). In terms of anthropogenic noise, Navy ships would contribute a correspondingly smaller amount of shipping noise compared to more common commercial shipping and boating (Mintz & Filadelfo, 2011; Mintz, 2012).

Impacts on fishes due to vessel noise are expected to be limited to minor behavioral responses, short-term physiological stress, and short periods of masking. However, long-term consequences for populations would not be expected. Predicted impacts on ESA-listed fish species and designated critical habitat would not be discernible from those described above in Section 3.6.3.1.5.2 (Impacts from Vessel Noise Under Alternative 1 for Training Activities).

Pursuant to the ESA, vessel noise during testing activities as described under Alternative 1 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.1.5.3 Impacts from Vessel Noise Under Alternative 2

Impacts from Vessel Noise Under Alternative 2 for Training Activities

Proposed Training Activities under Alternative 2 that involve vessel movement slightly increase from Training Activities proposed under Alternative 1, but the locations, types, and severity of impacts would not be discernible from those described above in Section 3.6.3.1.5.2 (Impacts from Vessel Noise Under Alternative 1 for Training Activities).

Pursuant to the ESA, vessel noise during training activities as described under Alternative 2 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks.

Impacts from Vessel Noise Under Alternative 2 for Testing Activities

Proposed Testing Activities under Alternative 2 that involve vessel movement slightly increase from Testing Activities proposed under Alternative 1, but the locations, types, and severity of impacts would not be discernible from those described above Section 3.6.3.1.5.2 (Impacts from Vessel Noise Under Alternative 1 for Testing Activities).

Pursuant to the ESA, vessel noise during testing activities as described under Alternative 2 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks.

3.6.3.1.5.4 Impacts from Vessel Noise Under the No Action Alternative

Impacts from Vessel Noise Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various acoustic stressors (e.g., vessel noise) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment either would remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.1.6 Impacts from Aircraft Noise

Fishes may be exposed to aircraft-generated overflight noise throughout the Study Area. A detailed description of the acoustic characteristics and typical sound produced by aircraft overflights are in Section 3.0.3.3 (Identifying Stressors for Analysis). Most of these sounds would be concentrated around airbases and fixed ranges within each of the range complexes. Aircraft noise could also occur in the waters immediately surrounding aircraft carriers at sea during takeoff and landing.

Aircraft produce extensive airborne noise from either turbofan or turbojet engines. A severe but infrequent type of aircraft noise is the sonic boom, produced when the aircraft exceeds the speed of sound. Rotary wing aircraft (helicopters) produce low-frequency sound and vibration (Pepper et al., 2003). Aircraft would pass quickly overhead and rotary-wing aircraft (e.g., helicopters) may hover for a few minutes at a time over the ocean. Aircraft overflights have the potential to affect surface waters and, therefore, to expose fish occupying those upper portions of the water column to sound.

Fish may be exposed to fixed-wing or rotary-wing aircraft-generated noise wherever aircraft overflights occur; however, sound is primarily transferred into the water from air in a narrow cone under the aircraft. Fish would have to be at or near the surface at the time of an overflight to be exposed to appreciable sound levels. Transmission of sound from a moving airborne source to a receptor underwater is influenced by numerous factors. These factors are discussed in detail in Appendix D (Acoustic and Explosive Concepts).

As discussed in Section 3.6.3.1.1.1 (Injury) and Section 3.6.3.1.1.2 (Hearing Loss), direct injury and hearing loss in fishes because of exposure to aircraft noise is highly unlikely to occur. Sounds from aircraft noise, including occasional sonic booms, lack the amplitude or duration to cause injury or hearing loss in fishes underwater (see Section 3.6.3.1, Acoustic Stressors). Due to the brief and dispersed nature of aircraft overflights, the risk of masking is very low. If masking were to occur it would only be during periods of time where a fish is at the surface while a hovering helicopter is directly overhead.

Fixed- and rotary-wing aircraft are used for a variety of training and testing activities throughout the Study Area. Fishes within close proximity to the activity and closer to the surface would have a higher probability of detecting these sounds, although exposure to aircraft noise would likely only last while the object is directly overhead. Training and testing events involving overflight noise are widely dispersed throughout the Study Area.

3.6.3.1.6.1 Methods for Analyzing Impacts from Aircraft Noise

The impacts on fishes due to exposure to aircraft noise are analyzed qualitatively by comparing reported observations under specific conditions as discussed in Section 3.6.3.1.1 (Background) to the conditions that fishes may be exposed to during proposed Navy activities.

3.6.3.1.6.2 Impacts from Aircraft Noise Under Alternative 1

<u>Impacts from Aircraft Noise Under Alternative 1 for Training Activities</u>

As described in Chapter 2 (Description of Proposed Action and Alternatives) and Section 3.0.3.3.1.5 (Aircraft Noise), training activities under Alternative 1 include fixed- and rotary-wing aircraft overflights. Certain portions of the Study Area such as areas near fleet concentration areas where planes are based are used more heavily by Navy aircraft than other portions. In addition, aircraft noise could also be concentrated about aircraft carries where flight takeoff and landing occur at sea. A detailed description of aircraft noise as a stressor is provided in Section 3.0.3.3.1.5 (Aircraft Noise).

In most cases, exposure of fishes to fixed-wing aircraft presence and noise would be brief as the aircraft quickly passes overhead. Fishes would have to be at or near the surface at the time of an overflight to be exposed to appreciable sound levels. Due to the low sound levels in water, it is unlikely that fishes would respond to most fixed-wing aircraft or transiting helicopters. Because most overflight exposure would be brief and aircraft noise would be at low received levels, only startle reactions, if any, are expected in response to low altitude flights. Similarly, the brief duration of most overflight exposures would limit any potential for masking of relevant sounds.

Daytime and nighttime activities involving helicopters may occur for extended periods of time, up to a couple of hours in some areas. During these activities, helicopters would typically transit throughout an area but could also hover over the water. Longer activity durations and periods of time where helicopters hover may increase the potential for behavioral reactions, startle reactions, masking, and physiological stress. Low-altitude flights of helicopters during some activities, which often occur under 100 ft. altitude, may elicit a stronger startle response due to the proximity of a helicopter to the water; the slower airspeed and longer exposure duration; and the downdraft created by a helicopter's rotor.

If fish were to respond to aircraft noise, only short-term behavioral or physiological reactions (e.g., avoidance and increased heart rate) would be expected. Therefore, long-term consequences for individuals would be unlikely and long-term consequences for populations are not expected.

Each ESA-listed species within the Study Area could be exposed to aircraft noise. However, due to the small area within which sound could potentially enter the water and the extremely brief window the sound could be present, exposures of ESA-listed fishes to aircraft noise would be extremely rare and, in the event that they did occur, would be very brief (seconds).

As discussed in the Section 3.6.2.2.2.1 (Status and Management) the majority of the designated physical and biological features (sites for spawning, sites for juvenile rearing, and sites for migration) for steelhead critical habitat occur in freshwater and estuaries, and do not occur within the offshore marine habitats of the Study Area. Therefore, the proposed training activities would not affect the critical habitat.

Pursuant to the ESA, aircraft noise during training activities as described under Alternative 1 would have no effect on designated critical habitat for steelhead but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, gulf grouper, giant manta rays and oceanic whitetip sharks.

Impacts from Aircraft Noise Under Alternative 1 for Testing Activities

As discussed in Chapter 2 (Description of the Proposed Action and Alternatives) and Section 3.0.3.3.1.5 (Aircraft Noise), testing activities under Alternative 1 include fixed- and rotary-wing aircraft overflights. Certain portions of the Study Area such as areas near fleet concentration areas and testing facilities where planes are based are used more heavily by Navy aircraft than other portions. Proposed testing activities under Alternative 1 that involve aircraft differ in number and location from training activities under Alternative 1; however, the types and severity of impacts would not be discernible from those described above in Section 3.6.3.1.6.2 (Impacts from Aircraft Noise Under Alternative 1 for Training Activities).

Each ESA-listed species within the Study Area could be exposed to aircraft noise. However, due to the small area within which sound could potentially enter the water and the extremely brief window the sound could be present, exposures of ESA-listed fishes to aircraft noise would be extremely rare and, in the event that they did occur, would be very brief (seconds).

As discussed in the Section 3.6.2.2.2.1 (Status and Management) the majority of the designated physical and biological features (sites for spawning, sites for juvenile rearing, and sites for migration) for steelhead critical habitat occur in freshwater and estuaries, and do not occur within the offshore marine habitats of the Study Area. Therefore, the proposed testing activities would not affect the critical habitat.

Pursuant to the ESA, aircraft noise during testing activities as described under Alternative 1 would have no effect on designated critical habitat for steelhead but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, gulf grouper, giant manta rays, and oceanic whitetip sharks.

3.6.3.1.6.3 Impacts from Aircraft Noise Under Alternative 2

Impacts from Aircraft Noise Under Alternative 2 for Training Activities

As discussed in Chapter 2 (Description of Proposed Action and Alternatives), and Section 3.0.3.3.1.5 (Aircraft Noise), training activities under Alternative 2 include a minor increase in the number of events that involve aircraft as compared to Alternative 1; however, the training locations, types of aircraft, and severity of predicted impacts would not be discernible from those described above in Section 3.6.3.1.6.2 (Impacts from Aircraft Noise Under Alternative 1 for Training Activities).

Pursuant to the ESA, aircraft noise during training activities as described under Alternative 2 would have no effect on designated critical habitat for steelhead but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, gulf grouper, giant manta rays, and oceanic whitetip sharks.

Impacts from Aircraft Noise Under Alternative 2 for Testing Activities

As discussed in Chapter 2 (Description of Proposed Action and Alternatives), and Section 3.0.3.3.1.5 (Aircraft Noise), testing activities under Alternative 2 include a minor increase in the number of events that involve aircraft noise as compared to Alternative 1; however, the testing locations, types of aircraft, and severity of predicted impacts would not be discernible from those described above in Section 3.6.3.1.6.2 (Impacts from Aircraft Noise Under Alternative 1 for Testing Activities).

Pursuant to the ESA, aircraft noise during testing activities as described under Alternative 2 would have no effect on designated critical habitat for steelhead but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, gulf grouper, giant manta rays, and oceanic whitetip sharks.

3.6.3.1.6.4 Impacts from Aircraft Noise Under the No Action Alternative

Impacts from Aircraft Noise Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various acoustic stressors (e.g., aircraft noise) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment either would remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.1.7 Impacts from Weapons Noise

Fishes could be exposed to noise from weapons firing, launch, flight downrange, and from the impact of non-explosive munitions on the water's surface. A detailed description of the acoustic characteristics of weapons noise is in Section 3.0.3.3.1.6 (Weapons Noise). Reactions by fishes to these specific stressors have not been recorded; however, fishes would be expected to react to weapons noise, as they would other transient sounds (Section 3.6.3.1.1.5, Behavioral Reactions).

3.6.3.1.7.1 Methods for Analyzing Impacts from Weapons Noise

The impacts on fishes due to exposure to weapons noise are analyzed qualitatively by comparing reported observations under specific conditions as discussed in Section 3.6.3.1.1 (Background) to the conditions which fishes may be exposed to during proposed Navy activities.

3.6.3.1.7.2 Impacts from Weapons Noise Under Alternative 1

Impacts from Weapons Noise Under Alternative 1 for Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), training activities under Alternative 1 include activities that produce in-water sound from weapons firing, launch, flight downrange, and non-explosive practice munitions impact with the water's surface. Training activities could occur throughout the Study Area but would be concentrated in the Southern California Range Complex, with fewer events in the Hawaii Range Complex, and minimal events in the HSTT Transit Corridor. Most activities involving large-caliber naval gunfire or the launching of targets, missiles, bombs, or other munitions are conducted more than 12 NM from shore. Impacts from training activities would be highly localized and concentrated in space and duration.

Mortality, injury, hearing loss and masking in fishes because of exposure to weapons noise is highly unlikely to occur. Sound from these sources lack the duration and high intensity to cause injury or hearing loss. Therefore, injury and hearing loss is not discussed further in this analysis. Due to the brief and dispersed nature of weapons noise, masking is also unlikely and not discussed further in this analysis. However, potential impacts considered are short-term behavioral or physiological reactions (e.g., swimming away and increased heart rate).

Animals at the surface of the water, in a narrow footprint under a weapons trajectory, could be exposed to naval gunfire sound and may exhibit brief behavioral reactions such as startle reactions or avoidance, or no reaction at all. Due to the short-term, transient nature of gunfire activities, animals may be exposed to multiple shots within a few seconds, but are unlikely to be exposed multiple times within a short period (minutes or hours). Behavioral reactions would likely be short term (minutes) and are unlikely to lead to substantial costs or long-term consequences for individuals or populations.

Sound due to missile and target launches is typically at a maximum during initiation of the booster rocket and rapidly fades as the missile or target travels downrange. Many missiles and targets are launched from aircraft, which would produce minimal sound in the water due to the altitude of the aircraft at launch. Behavioral reactions would likely be short term (minutes) and are unlikely to lead to long-term consequences for individuals or populations.

As discussed in Section 3.0.3.3.1.6 (Weapons Noise), any objects that are dropped and impact the water with great force could produce a loud broadband sound at the water's surface. Large-caliber non-explosive projectiles, non-explosive bombs, and intact missiles and targets could produce a large impulse upon impact with the water surface (McLennan, 1997). Fishes within a few meters could experience some temporary hearing loss, although the probability is low of the non-explosive munitions landing within this range while a fish is near the surface. Animals within the area may hear the impact of objects on the surface of the water and would likely alert, dive, or avoid the immediate area. Impact noise would not be expected to induce significant behavioral reactions from fishes, and long-term consequences for individuals and populations are unlikely.

All ESA-listed species within the Study Area could be exposed to weapons noise. ESA-listed fishes that are exposed to weapons noise may exhibit minor behavioral reactions or physiological stress. Due to the short-term, transient nature of weapons noise, fish are unlikely to be exposed multiple times within a short period (seconds to minutes), or across multiple days. Physiological stress and behavioral reactions would likely be short-term (seconds or minutes), and substantive costs or long-term consequences for individuals or populations would not be expected.

As discussed in the Section 3.6.2.2.2.1 (Status and Management) the majority of the designated physical and biological features (sites for spawning, sites for juvenile rearing, and sites for migration) for steelhead critical habitat occur in freshwater and estuaries, and do not occur within the offshore marine habitats of the Study Area.

Pursuant to the ESA, weapons noise during training activities as described under Alternative 1 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from Weapons Noise Under Alternative 1 for Testing Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), testing activities under Alternative 1 include activities that produce weapons noise. Testing activities could occur in the Southern California and Hawaii Range Complexes. Most activities involving large-caliber naval gunfire or the launching of targets, missiles, bombs, or other munitions are conducted more than 12 NM from shore. Proposed testing activities under Alternative 1 differ in number and location from training activities under Alternative 1; however, the types and severity of impacts would not be discernible from those described above in Section 3.6.3.1.7.2 (Impacts from Weapons Noise Under Alternative 1 for Training Activities). Impacts on fish due to weapons noise are expected to be limited to short-term, minor behavioral responses, physiological stress, and short periods of masking; long-term consequences for an individual, and therefore populations, would not be expected.

Pursuant to the ESA, weapons noise during testing activities as described under Alternative 1 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.1.7.3 Impacts from Weapons Noise Under Alternative 2

Impacts from Weapons Noise Under Alternative 2 for Training Activities

Proposed training activities under Alternative 2 that produce weapons noise differ in number and location from training activities under Alternative 1; however, the types and severity of impacts would not be discernible from those described above in Section 3.6.3.1.7.2 (Impacts from Weapons Noise Under Alternative 1 for Training Activities). Impacts on fishes due to weapons noise are expected to be limited to minor behavioral responses, short-term physiological stress, and short periods of masking; furthermore, long-term consequences for an individual, and therefore populations, would not be expected.

Pursuant to the ESA, weapons noise during training activities as described under Alternative 2 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks.

Impacts from Weapons Noise Under Alternative 2 for Testing Activities

Proposed testing activities under Alternative 2 that produce weapons noise differ in number and location from testing activities under Alternative 1; however, the types and severity of impacts would not be discernible from those described above in Section 3.6.3.1.7.2 (Impacts from Weapons Noise Under Alternative 1 for Training Activities). Impacts on fishes due to weapons noise are expected to be limited to minor behavioral responses, short-term physiological stress, and short periods of masking; long-term consequences for an individual, and therefore populations, would not be expected.

Pursuant to the ESA, weapons noise during testing activities as described under Alternative 2 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks.

3.6.3.1.7.4 Impacts from Weapons Noise Under the No Action Alternative

Impacts from Weapons Noise Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various acoustic stressors (e.g., weapons noise) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment either would remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.2 Explosive Stressors

Explosions in the water or near the water surface can introduce loud, impulsive, broadband sounds into the marine environment. However, unlike acoustic stressors, explosives release energy at a high rate, producing a shock wave that can be injurious and even deadly. Therefore, explosive impacts on fishes are discussed separately from other acoustic stressors, even though the analysis of explosive impacts will in part rely on data from fishes exposed to impulsive sources where appropriate.

Explosives are usually described by their net explosive weight, which accounts for the weight and type of explosive material. Additional explanation of the acoustic and explosive terms and sound energy concepts used in this section is found in Appendix D (Acoustic and Explosive Concepts).

The ways in which an explosive exposure could result in immediate effects or lead to long-term consequences for an animal are explained in Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities), and the below background section follows that framework. The following Background section discusses what is currently known about effects of explosives on fishes.

3.6.3.2.1 Background

The effects of explosions on fishes have been studied and reviewed by numerous authors (Keevin & Hempen, 1997; O'Keeffe, 1984; O'Keeffe & Young, 1984; Popper et al., 2014). A summary of the literature related to each type of effect forms the basis for analyzing the potential effects from Navy activities. The sections below include a survey and synthesis of best-available-science published in peer-reviewed journals, technical reports, and other scientific sources pertinent to impacts on fishes potentially resulting from Navy training and testing activities. Fishes could be exposed to a range of impacts depending on the explosive source and context of the exposure. In addition to acoustic impacts including temporary or permanent hearing loss, auditory masking, physiological stress, or changes in behavior, potential impacts from an explosive exposure can include non-lethal injury and mortality.

3.6.3.2.1.1 Injury

Injury refers to the direct effects on the tissues or organs of a fish. The blast wave from an in-water explosion is lethal to fishes at close range, causing massive organ and tissue damage (Keevin & Hempen, 1997). At greater distance from the detonation point, the extent of mortality or injury depends on a number of factors including fish size, body shape, depth, physical condition of the fish, and perhaps most importantly, the presence of a swim bladder (Keevin & Hempen, 1997; Wright, 1982; Yelverton et al., 1975; Yelverton & Richmond, 1981). At the same distance from the source, larger fishes are generally less susceptible to death or injury, elongated forms that are round in cross-section are less at risk than deep-bodied forms, and fishes oriented sideways to the blast suffer the greatest impact (Edds-Walton & Finneran, 2006; O'Keeffe, 1984; O'Keeffe & Young, 1984; Wiley et al., 1981; Yelverton et al., 1975). Species with a swim bladder are much more susceptible to blast injury from explosives than fishes without them (Gaspin, 1975; Gaspin et al., 1976; Goertner et al., 1994).

If a fish is close to an explosive detonation, the exposure to rapidly changing high pressure levels can cause barotrauma. Barotrauma is injury due to a sudden difference in pressure between an air space inside the body and the surrounding water and tissues. Rapid compression followed by rapid expansion of airspaces, such as the swim bladder, can damage surrounding tissues and result in the rupture of the airspace itself. The swim bladder is the primary site of damage from explosives (Wright, 1982; Yelverton et al., 1975). Gas-filled swim bladders resonate at different frequencies than surrounding tissue and can be torn by rapid oscillation between high- and low-pressure waves (Goertner, 1978). Swim bladders are a characteristic of most bony fishes with the notable exception of flatfishes (e.g., halibut). Sharks and rays are examples of fishes without a swim bladder. Small airspaces, such as micro-bubbles that may be present in gill structures, could also be susceptible to oscillation when exposed to the rapid pressure increases caused by an explosion. This may have caused the bleeding observed on gill structures of some fish exposed to explosions (Goertner et al., 1994). Sudden very high pressures can also cause damage at tissue interfaces due to the way pressure waves travel differently through tissues with different densities. Rapidly oscillating pressure waves might rupture the kidney, liver, spleen, and sinus and cause venous hemorrhaging (Keevin & Hempen, 1997).

Several studies have exposed fish to explosives and examined various metrics in relation to injury susceptibility. Sverdrup (1994) exposed Atlantic salmon (1 to 1.5 kg [2 to 3 lb.]) in a laboratory setting to repeated shock pressures of around 2 megapascals (300 pounds per square inch) without any immediate or delayed mortality after a week. Hubbs and Rechnitzer (1952) showed that fish with swim bladders exposed to explosive shock fronts (the near-instantaneous rise to peak pressure) were more susceptible to injury when several feet below the water surface than near the bottom. When near the surface, the fish began to exhibit injuries around peak pressure exposures of 40 to 70 pounds per square inch. However, near the bottom (all water depths were less than 100 ft.) fish exposed to pressures over twice as high exhibited no sign of injury. Yelverton et al. (1975) similarly found that peak pressure was not correlated to injury susceptibility. Yelverton et al. (1975) instead found that injury susceptibility of swim bladder fish at shallow depths (10 ft. or less) was correlated to the metric of positive impulse

(Pa-s), which takes into account both the positive peak pressure, the duration of the positive pressure exposure, and the fish mass, with smaller fish being more susceptible.

Gaspin et al. (1976) exposed multiple species of fish with a swim bladder, placed at varying depths, to explosive blasts of varying size and depth. Goertner (1978) and Wiley (1981) developed a swim bladder oscillation model, which showed that the severity of injury observed in those tests could be correlated to the extent of swim bladder expansion and contraction predicted to have been induced by exposure to the explosive blasts. Per this model, the degree of swim bladder oscillation is affected by ambient pressure (i.e., depth of fish), peak pressure of the explosive, duration of the pressure exposure, and exposure to surface rarefaction (negative pressure) waves. The maximum potential for injury is predicted to occur where the surface reflected rarefaction (negative) pressure wave arrives coincident with the moment of maximum compression of the swim bladder caused by exposure to the direct positive blast pressure wave, resulting in a subsequent maximum expansion of the swim bladder. Goertner (1978) and Wiley et al. (1981) found that their swim bladder oscillation model explained the injury data in the Yelverton et al. (1975) exposure study and their impulse parameter was applicable only to fishes at shallow enough depths to experience less than one swim bladder oscillation before being exposed to the following surface rarefaction wave.

O'Keeffe (1984) provides calculations and contour plots that allow estimation of the range to potential effects of in-water explosions on fish possessing swim bladders using the damage prediction model developed by Goertner (1978). O'Keeffe's (1984) parameters include the charge weight, depth of burst, and the size and depth of the fish, but the estimated ranges do not take into account unique propagation environments that could reduce or increase the range to effect. The 10 percent mortality range shown below in Table 3.6-12 is the maximum horizontal range predicted by O'Keeffe (1984) for 10 percent of fish suffering injuries that are expected to not be survivable (e.g., damaged swim bladder or severe hemorrhaging). Fish at greater depths and near the surface are predicted to be less likely to be injured because geometries of the exposures would limit the amplitude of swim bladder oscillations.

In contrast to fish with swim bladders, fishes without swim bladders have been shown to be more resilient to explosives (Gaspin, 1975; Gaspin et al., 1976; Goertner et al., 1994). For example, some small (average 116 mm length; approximately 1 oz.) hogchokers (*Trinectes maculatus*) exposed less than 5 ft. from a 10 lb. pentolite charge immediately survived the exposure with slight to moderate injuries, and only a small number of fish were immediately killed; however, most of the fish at this close range did suffer moderate to severe injuries, typically of the gills or around the otolithic structures (Goertner et al., 1994).

Studies that have documented caged fishes killed during planned in-water explosions indicate that most fish that die do so within one to four hours, and almost all die within a day (Yelverton et al., 1975). Mortality in free-swimming (uncaged) fishes may be higher due to increased susceptibility to predation. Fitch and Young (1948) found that the type of free-swimming fish killed changed when blasting was repeated at the same location within 24 hours of previous blasting. They observed that most fish killed on the second day were scavengers, presumably attracted by the victims of the previous day's blasts.

Fitch and Young (1948) also investigated whether a significant portion of fish killed would have sunk and not been observed at the surface. Comparisons of the numbers of fish observed dead at the surface and at the bottom in the same affected area after an explosion showed that fish found dead on the bottom comprised less than 10 percent of the total observed mortality. Gitschlag et al. (2000) conducted a more detailed study of both floating fishes and those that were sinking or lying on the bottom after explosive removal of nine oil platforms in the northern Gulf of Mexico. Results were highly variable. They found that 3 to 87 percent (46 percent average) of the red snapper killed during a blast might float to the surface. Currents, winds, and predation by seabirds or other fishes may be some of the reasons that the magnitude of fish mortality may not have been accurately captured (Settle et al., 2002).

Table 3.6-12: Range to Effect from In-water Explosions for Fishes with a Swim Bladder

Weight of Pentolite (lb.) [NEW, lb.][1]	*Depth of Explosion (ft.) [m]*	*10% Mortality Maximum Range (ft.) [m]*		
		1 oz. Fish	***1 lb. Fish***	***30 lb. Fish***
10 [13]	10 [3]	530 [162]	315 [96]	165 [50]
	50 [15]	705 [214]	425 [130]	260 [79]
	200 [61]	905 [276]	505 [154]	290 [88]
100 [130]	10 [3]	985 [300]	600 [183]	330 [101]
	50 [15]	1,235 [376]	865 [264]	590 [180]
	200 [61]	1,340 [408]	1,225 [373]	725 [221]
1,000 [1,300]	10 [3]	1,465 [447]	1,130 [344]	630 [192]
	50 [15]	2,255 [687]	1,655 [504]	1,130 [344]
	200 [61]	2,870 [875]	2,390 [728]	1,555 [474]
10,000 [13,000]	10 [3]	2,490 [759]	1,920 [585]	1,155 [352]
	50 [15]	4,090 [1,247]	2,885 [879]	2,350 [716]
	200 [61]	5,555 [1,693]	4,153 [1,266]	3,090 [942]

[1] Explosive weights of pentolite converted to net explosive weight using the peak pressure parameters in Swisdak (1978).
Notes: lb. = pounds, NEW = net explosive weight, oz. = ounce. Data from O'Keeffe (1984).

There have been few studies of the impact of underwater explosives on early life stages of fish (eggs, larvae, juveniles). Fitch and Young (1948) reported mortality of larval anchovies exposed to underwater blasts off California. Nix and Chapman (1985) found that anchovy and smelt larvae died following the detonation of buried charges. Similar to adult fishes, the presence of a swim bladder contributes to shock wave-induced internal damage in larval and juvenile fish (Settle et al., 2002). Explosive shock wave injury to internal organs of larval pinfish and spot exposed at shallow depths was documented by Settle et al. (2002) and Govoni et al. (2003; 2008) at impulse levels similar to those predicted by Yelverton et al. (1975) for very small fish. Settle et al. (2002) provide the lowest measured received level that injuries have been observed in larval fish. Researchers (Faulkner et al., 2006; Faulkner et al., 2008; Jensen, 2003) have suggested that egg mortality may be correlated with peak particle velocity exposure (i.e., the localized movement or shaking of water particles, as opposed to the velocity of the blast wave), although sufficient data from direct explosive exposures is not available.

Rapid pressure changes could cause mechanical damage to sensitive ear structures due to differential movements of the otolithic structures. Bleeding near otolithic structures was the most commonly observed injury in non-swim bladder fish exposed to a close explosive charge (Goertner et al., 1994).

General research findings regarding injury in fishes due to exposure to other impulsive sound sources are discussed under Section 3.6.3.1.1.1 (Injury due to Impulsive Sound Sources). Results from other impulsive sound exposure studies, such as those for seismic air guns and impact pile driving, may be useful in interpreting effects where data are lacking for explosive sources. As summarized by the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), exposure to explosive energy poses the greatest potential threat for injury and mortality in marine fishes. However, thresholds for the onset of injury from exposure to explosives are not currently available, and recommendations in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014) only provide qualitative criteria for consideration. Therefore, available data from existing explosive studies are used to estimate a threshold to the onset of injury (see discussion below under Section 3.6.3.2.2.1, Methods for Analyzing Impacts from Explosives). In general, fishes with a swim bladder are more susceptible to injury than fishes without a swim bladder. The susceptibility also probably varies with size and depth of both the detonation and the fish. Fish larvae or juvenile fish may be more susceptible to injury from exposure to explosives.

3.6.3.2.1.2 Hearing Loss

There are no direct measurements of hearing loss in fishes due to exposure to explosive sources. The sound resulting from an explosive detonation is considered an impulsive sound and shares important qualities (i.e., short duration and fast rise time) with other impulsive sounds such as those produced by air guns. PTS in fish has not been known to occur in species tested to date and any hearing loss in fish may be as temporary as the timeframe required to repair or replace the sensory cells that were damaged or destroyed (Popper et al., 2005; Popper et al., 2014; Smith et al., 2006).

As reviewed in Popper et al. (2014), fishes without a swim bladder, or fishes with a swim bladder not involved in hearing, would be less susceptible to hearing loss (i.e., TTS), even at higher level exposures. Fish with a swim bladder involved in hearing may be susceptible to TTS within very close ranges to an explosive. General research findings regarding TTS in fishes as well as findings specific to exposure to other impulsive sound sources are discussed in Section 3.6.3.1.1.2 (Hearing Loss).

3.6.3.2.1.3 Masking

Masking refers to the presence of a noise that interferes with a fish's ability to hear biologically important sounds including those produced by prey, predators, or other fish in the same species (Myrberg, 1980; Popper et al., 2003). This can take place whenever the noise level heard by a fish exceeds the level of a biologically relevant sound. As discussed in Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) masking only occurs in the presence of the masking noise and does not persist after the cessation of the noise. Masking may lead to a change in vocalizations or a change in behavior (e.g., cessation of foraging, leaving an area).

There are no direct observations of masking in fishes due to exposure to explosives. The *ANSI Sound Exposure Guideline* technical report (2014) highlights a lack of data that exist for masking by explosives but suggests that the intermittent nature of explosions would result in very limited probability of any masking effects and, if masking occurred, it would only occur during the duration of the sound. General research findings regarding masking in fishes due to exposure to sound are discussed in detail in Section 3.6.3.1.1.3 (Masking). Potential masking from explosives is likely to be similar to masking studied for other impulsive sounds such as air guns.

3.6.3.2.1.4 Physiological Stress

Fishes naturally experience stress within their environment and as part of their life histories. The stress response is a suite of physiological changes that are meant to help an organism mitigate the impact of a stressor. However, if the magnitude and duration of the stress response is too great or too long, then it can have negative consequences to the organism (e.g., decreased immune function, decreased reproduction). Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) provides additional information on physiological stress and the framework used to analyze this potential impact.

Research on physiological stress in fishes due to exposure to explosive sources is limited. Sverdrup et al. (1994) studied levels of stress hormones in Atlantic salmon after exposure to multiple detonations in a laboratory setting. Increases in cortisol and adrenaline were observed following the exposure, with adrenaline values returning to within normal range within 24 hours. General research findings regarding physiological stress in fishes due to exposure to impulsive sources are discussed in detail in Section 3.6.3.1.1.4 (Physiological Stress). Generally, stress responses are more likely to occur in the presence of potentially threatening sound sources such as predator vocalizations or the sudden onset of impulsive signals. Stress responses may be brief (a few seconds to minutes) if the exposure is short or if fishes habituate or learn to tolerate the noise. It is assumed that any physiological response (e.g., hearing loss or injury) or significant behavioral response is also associated with a stress response.

3.6.3.2.1.5 Behavioral Reactions

As discussed in Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities), any stimuli in the environment can cause a behavioral response in fishes, including sound and energy produced by explosions. Behavioral reactions of fishes to explosions have not been recorded. Behavioral reactions from explosive sounds are likely to be similar to reactions studied for other impulsive sounds such as those produced by air guns. Impulsive signals, particularly at close range, have a rapid rise time and higher instantaneous peak pressure than other signal types, making them more likely to cause startle or avoidance responses. General research findings regarding behavioral reactions from fishes due to exposure to impulsive sounds, such as those associated with explosions, are discussed in detail in Section 3.6.3.1.1.5 (Behavioral Reactions).

As summarized by the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), species may react differently to the same sound source depending on a number of variables, such as the animal's life stage or behavioral state (e.g., feeding, mating). Without data that are more specific it is assumed that fishes with similar hearing capabilities react similarly to all impulsive sounds outside or within the zone for hearing loss and injury. Observations of fish reactions to large-scale air gun surveys are informative, but not necessarily directly applicable to analyzing impacts from the short-term, intermittent use of all impulsive sources. Fish have a higher probability of reacting when closer to an impulsive sound source (within tens of meters), and a decreasing probability of reaction at increasing distances (Popper et al., 2014).

3.6.3.2.1.6 Long-term Consequences

Long-term consequences to a population are determined by examining changes in the population growth rate. For additional information on the determination of long-term consequences, see Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities). Physical effects from explosive sources that could lead to a reduction in the population growth rate include mortality or injury, which could remove animals from the reproductive pool, and permanent hearing impairment or chronic masking, which could affect navigation, foraging, predator avoidance, or communication. The long-term consequences due to individual behavioral reactions, masking, and short-term instances of physiological stress are especially difficult to predict because individual experience over time can create complex contingencies, especially for fish species that live for multiple seasons or years. For example, a lost reproductive opportunity could be a measurable cost to the individual; however, short-term costs may be recouped during the life of an otherwise healthy individual. These factors are taken into consideration when assessing risk of long-term consequences.

3.6.3.2.2 Impacts from Explosives

Fishes could be exposed to energy and sound from in-water and in-air explosions associated with proposed activities. General categories and characteristics of explosives and the numbers and sizes of detonations proposed are described in Section 3.0.3.3.2 (Explosive Stressors). The activities analyzed in the EIS/OEIS that use explosives are also described in Appendix A (Navy Activity Descriptions).

As discussed throughout Section 3.6.3.2.1 (Background), sound and energy from in-water explosions are capable of causing mortality, injury, hearing loss, masking, physiological stress, or a behavioral response, depending on the level and duration of exposure. The death of an animal would eliminate future reproductive potential, which is considered in the analysis of potential long-term consequences to the population. Exposures that result in non-auditory injuries may limit an animal's ability to find food, communicate with other animals, or interpret the surrounding environment. Impairment of these abilities can decrease an individual's chance of survival or affect its ability to reproduce. Temporary threshold shift can also impair an animal's abilities, although the individual may recover quickly with little significant effect.

3.6.3.2.2.1 Methods for Analyzing Impacts from Explosives

The Navy performed a quantitative analysis to estimate ranges to effect for fishes exposed to in-water explosives during Navy training and testing activities. Inputs to the quantitative analysis included sound propagation modeling in the Navy's Acoustic Effects Model to the sound exposure criteria and thresholds presented below. Density data for fish species within the Study Area are not currently available; therefore, it is not possible to estimate the total number of individuals that may be affected by explosive activities.

Criteria and Thresholds Used to Estimate Impacts on Fishes from Explosives

Mortality and Injury from Explosives

Criteria and thresholds to estimate impacts from sound and energy produced by explosive activities are presented below in Table 3.6-13. In order to estimate the longest range at which a fish may be killed or mortally injured, the Navy based the threshold for mortal injury on the lowest pressure that caused mortalities in the study by Hubbs and Rechnitzer (1952), consistent with the recommendation in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014). As described in Section 3.6.3.1.1.1 (Injury), this threshold likely over-estimates the potential for mortal injury. The potential for mortal injury has been shown to be correlated to fish size, depth, and geometry of exposure, which are not accounted for by using a peak pressure threshold. However, until fish mortality models are developed that can reasonably consider these factors across multiple environments, use of the peak pressure threshold allows for a conservative estimate of maximum impact ranges.

Due to the lack of detailed data for onset of injury in fishes exposed to explosives, thresholds from impact pile driving exposures (Halvorsen et al., 2011; Halvorsen et al., 2012a; Halvorsen et al., 2012b) were used as a proxy for the analysis in the HSTT DEIS. Upon re-evaluation during consultation, it was decided that pile driving thresholds are too conservative and not appropriate to use in the analysis of explosive effects on fishes. Therefore, injury criteria were revised as follows.

Thresholds for the onset of injury from exposure to explosives are not currently available, and recommendations in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014) only provide qualitative criteria for consideration. Therefore, available data from existing explosive studies were reviewed to provide a conservative estimate for a threshold to the onset of injury (Gaspin, 1975; Gaspin et al., 1976; Govoni et al., 2003; Govoni et al., 2008; Hubbs & Rechnitzer, 1952; Settle et al., 2002; Yelverton et al., 1975). It is important to note that some of the available literature is not peer reviewed and may have some caveats to consider when reviewing the data (e.g., issues with controls, limited details on injuries observed), but this information may still provide a better understanding of where injurious effects would begin to occur specific to explosive activities. The lowest thresholds at which injuries were observed in each study were recorded and compared for consideration in selecting criteria. As a conservative measure, the absolute lowest peak sound pressure level recorded that resulted in injury, observed in exposures of larval fishes to explosions (Settle et al., 2002), was selected to represent the threshold to injury (see Table 3.6-13).

The injury threshold is consistent across all fish, regardless of hearing group, due to the lack of rigorous data for multiple species. It is important to note that these thresholds may be overly conservative as there is evidence that fishes exposed to higher thresholds than the those in Table 3.6-13 have shown no signs of injury (depending on variables such as the weight of the fish, size of the explosion, and depth of the cage). It is likely that adult fishes and fishes without a swim bladder would be less susceptible to injury than more sensitive hearing groups and larval species.

Table 3.6-13: Sound Exposure Criteria for Mortality and Injury from Explosives

Fish Hearing Group	*Onset of Mortality*	*Onset of Injury*
	SPL_{peak}	*SPL_{peak}*
Fishes without a swim bladder	229	220
Fishes with a swim bladder not involved in hearing	229	220
Fishes with a swim bladder involved in hearing	229	220
Fishes with a swim bladder and high-frequency hearing	229	220

Note: SPL_{peak} = Peak sound pressure level.

The number of fish killed by an in-water explosion would depend on the population density near the blast, as well as factors discussed throughout Section 3.6.3.2.1.1 (Injury) such as net explosive weight, depth of the explosion, and fish size. For example, if an explosion occurred in the middle of a dense school of menhaden, herring, or other schooling fish, a large number of fish could be killed. However, the probability of this occurring is low based on the patchy distribution of dense schooling fish. Stunning from pressure waves could also temporarily immobilize fish, making them more susceptible to predation.

Fragments produced by exploding munitions at or near the surface may present a high-speed strike hazard for an animal at or near the surface. In water, however, fragmentation velocities decrease rapidly due to drag (Swisdak & Montanaro, 1992). Because blast waves propagate efficiently through water, the range to injury from the blast wave would likely extend beyond the range of fragmentation risk.

Hearing Loss from Explosives

Criteria and thresholds to estimate TTS from sound produced by explosive activities are presented below in Table 3.6-14. Direct (measured) TTS data from explosives are not available. Criteria used to define TTS from explosives is derived from data on fishes exposed to seismic air gun signals (Popper et al., 2005) as summarized in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014). TTS has not been documented in fishes without a swim bladder from exposure to other impulsive sources (pile driving and air guns). Although it is possible that fishes without a swim bladder could receive TTS from exposure to explosives, fishes without a swim bladder are typically less susceptible to hearing impairment than fishes with a swim bladder. If TTS occurs in fishes without a swim bladder, it would likely occur within the range of injury; therefore, no thresholds for TTS are proposed. General research findings regarding hearing loss in fishes as well as findings specific to exposure to other impulsive sound sources are discussed in Section 3.6.3.1.1.2 (Hearing Loss Due to Impulsive Sound Sources).

Table 3.6-14: Sound Exposure Criteria for Hearing Loss from Explosives

Fish Hearing Group	*TTS (SEL_{cum})*
Fishes without a swim bladder	NC
Fishes with a swim bladder not involved in hearing	> 186
Fishes with a swim bladder involved in hearing	186
Fishes with a swim bladder and high-frequency hearing	186

Notes: TTS = Temporary Threshold Shift, SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micropascal squared seconds [dB re 1 μPa^2-s]), NC = no criteria are reported, “>” indicates that the given effect would occur above the reported threshold.

As discussed in Section 3.6.3.1.1.2 (Hearing Loss), exposure to sound produced from seismic air guns at a cumulative sound exposure level of 186 dB re 1 μPa^2-s has resulted in TTS in fishes with a swim bladder involved in hearing (Popper et al., 2005). TTS has not occurred in fishes with a swim bladder not involved in hearing and would likely occur above the given threshold in Table 3.6-14.

3.6.3.2.2.2 Impact Ranges for Explosives

The following section provides estimated range to effects for fishes exposed to sound and energy produced by explosives. Ranges are calculated using criteria from Table 3.6-13 and Table 3.6-14 and the Navy Acoustic Effects Model. Fishes within these ranges would be predicted to receive the associated effect. Ranges may vary greatly depending on factors such as the cluster size, location, depth, and season of the activity.

Table 3.6-15 provides range to mortality and injury for all fishes. Only one table (Table 3.6-16) is provided for range to TTS for all fishes with a swim bladder. However, ranges to TTS for fishes with a swim bladder not involved in hearing would be shorter than those reported because this effect has not been observed from the designated threshold in Table 3.6-14.

Table 3.6-15: Range to Mortality and Injury for All Fishes from Explosives

Bin	Range to Effects (meters)	
	Onset of Mortality	Onset of Injury
	SPL_{peak}	SPL_{peak}
E1 (0.25 lb. NEW)	49 (35–65)	121 (55–310)
E2 (0.5 lb. NEW)	62 (40–75)	150 (60–210)
E3 (2.5 lb. NEW)	107 (55–310)	278 (90–875)
E4 (5 lb. NEW)	160 (140–430)	406 (310–825)
E5 (10 lb. NEW)	172 (65–500)	417 (120–1,025)
E6 (20 lb. NEW)	217 (75–525)	516 (140–1,275)
E7 (60 lb. NEW)	419 (300–825)	985 (625–1,775)
E8 (100 lb. NEW)	444 (320–1,025)	1,192 (470–3,775)
E9 (250 lb. NEW)	497 (370–600)	1,021 (500–1,275)
E10 (500 lb. NEW)	605 (200–775)	1,332 (360–1,775)
E11 (650 lb. NEW)	984 (650–3,025)	2,771 (1,275–7,525)
E12 (1,000 lb. NEW)	776 (450–1,025)	1,737 (600–2,025)
E16 (14,500 lb. NEW)	3,382 (1,775–8,025)	6,368 (4,775–10,275)

Notes: SPL_{peak} = Peak sound pressure level. Range to effects represent modeled predictions in different areas and seasons within the Study Area. Each cell contains the estimated average, minimum and maximum range to the specified effect.

Table 3.6-16: Range to TTS for Fishes with a Swim Bladder from Explosives

Bin	Cluster Size	*Range to Effects (meters)* TTS[1] SEL_{cum}
E1 (0.25 lb. NEW)	1	< 50 (40–65)
	200	< 573 (160–1,525)
E2 (0.5 lb. NEW)	1	< 58 (45–150)
E3 (2.5 lb. NEW)	1	< 125 (65–300)
	12	< 399 (120–1,025)
E4 (5 lb. NEW)	1	< 250 (160–550)
E5 (10 lb. NEW)	1	< 193 (85–900)
	25	< 802 (200–4,775)
E6 (20 lb. NEW)	1	< 256 (95–1,525)
E7 (60 lb. NEW)	1	< 1,000 (525–2,525)
E8 (100 lb. NEW)	1	< 704 (300–2,025)
E9 (250 lb. NEW)	1	< 564 (360–1,275)
E10 (500 lb. NEW)	1	< 746 (280–1,775)
E11 (650 lb. NEW)	1	< 2,200 (1,525–7,525)
E12 (1,000 lb. NEW)	1	< 813 (460–1,775)

Notes: SEL_{cum} = Cumulative sound exposure level, TTS = Temporary Threshold Shift, "<" indicates that the given effect would occur at distances less than the reported range(s). Range to effects represent modeled predictions in different areas and seasons within the Study Area. Each cell contains the estimated average, minimum and maximum range to the specified effect.

3.6.3.2.2.3 Impacts from Explosives Under Alternative 1

Impacts from Explosives Under Alternative 1 for Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Section 3.0.3.3.2 (Explosive Stressors), and Appendix A (Navy Activity Descriptions), training activities under Alternative 1 would use underwater detonations and explosive munitions. Training activities involving explosions could occur anywhere within the Study Area with higher concentrations in the Southern California Range Complex. Activities that involve underwater detonations and explosive munitions typically occur more than 3 NM from shore; however, most mine warfare and demolition activities would also occur in shallow water close to shore. The Navy will implement mitigation to avoid potential impacts on hammerhead sharks in the Southern California Range Complex during explosive mine neutralization activities involving Navy divers, as discussed below and in Section 5.3.3 (Explosive Stressors). In addition to procedural mitigation, the Navy will implement mitigation to avoid impacts from explosives on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources), which will consequently also help avoid potential impacts on fishes that shelter and feed on shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks.

Sound and energy from explosions could result in mortality and injury, on average, for hundreds to even thousands of meters from some of the largest explosions. Exposure to explosions could also result in hearing loss in nearby fishes. The estimated range to each of these effects based on explosive bin size is provided in Table 3.6-15 and Table 3.6-16. Generally, explosives that belong to larger bins (with large net explosive weights) produce longer ranges within each effect category. However, some ranges vary depending upon a number of other factors (e.g., number of explosions in a single activity, depth of the charge, etc.). Fishes without a swim bladder, adult fishes, and larger species would generally be less susceptible to injury and mortality from sound and energy associated with explosive activities than small, juvenile, or larval fishes. Fishes that experience hearing loss could miss opportunities to detect predators or prey, or show a reduction in interspecific communication.

If an individual fish were repeatedly exposed to sound and energy from in-water explosions that caused alterations in natural behavioral patterns or physiological stress, these impacts could lead to long-term consequences for the individual such as reduced survival, growth, or reproductive capacity. If detonations occurred close together (within a few seconds), there could be the potential for masking to occur, but this would likely happen at farther distances from the source where individual detonations might sound more continuous. Training activities involving explosions are generally dispersed in space and time. Consequently, repeated exposure of individual fishes to sound and energy from in-water explosions over the course of a day or multiple days is not likely, and most behavioral effects are expected to be short-term (seconds or minutes) and localized. Exposure to multiple detonations over the course of a day would most likely lead to an alteration of natural behavior or the avoidance of that specific area.

As discussed previously in Section 3.6.2.1.3 (Hearing and Vocalization), all ESA-listed fish species that occur in the Study Area are capable of detecting sound and energy produced by explosives. Scalloped hammerhead sharks in the Eastern Pacific Distinct Population Segment, steelhead and gulf grouper could be exposed to activities that involve the use of explosives within the Southern California Range Complex. However, occurrence of scalloped hammerhead sharks in Southern California is limited due to their preference for warm water temperatures. Scalloped hammerhead sharks are transient and if they do occur in the Southern California Range Complex, it would only be during times of the year when water temperatures increase or during unusually warm years (e.g., El Nino). In an effort to avoid potential impacts on scalloped hammerhead sharks within the Eastern Pacific Distinct Population Segment during explosive mine neutralization activities involving Navy divers in the Southern California Range Complex, the Navy will implement mitigation that includes ceasing detonations or fuse initiations if a hammerhead shark is observed in the mitigation zone (see Section 5.3.3, Explosive Stressors). In addition, adult steelhead may only be exposed for limited periods of time throughout the year in nearshore and offshore areas, depending on seasonality and type of spawning migration (winter-run versus summer-run) back into rivers. Giant manta rays and oceanic whitetip sharks may be exposed throughout the offshore portions of the Study Area. Gulf grouper are demersal reef fish and live close to the seafloor therefore would not be exposed to explosive activities.

Impacts on ESA-listed fishes, if they occur, would be similar to impacts on fishes in general. However, due to the short-term, infrequent and localized nature of these activities, ESA-listed fishes are unlikely to be exposed multiple times within a short period. In addition, physiological and behavioral reactions would be expected to be brief (seconds to minutes) and infrequent based on the low probability of co-occurrence between training activities and these species. Although individual individuals may be impacted, long-term consequences for populations would not be expected.

As discussed in the Section 3.6.2.2.2.1 (Status and Management) the majority of the designated physical and biological features (sites for spawning, sites for juvenile rearing, and sites for migration) for steelhead critical habitat occur in freshwater and estuaries, and do not occur within the offshore marine habitats of the Study Area. Therefore, the proposed training activities would not affect the critical habitat.

Pursuant to the ESA, the use of explosives during training activities as described under Alternative 1 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from Explosives Under Alternative 1 for Testing Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Section 3.0.3.3.2 (Explosive Stressors), and Appendix A (Navy Activity Descriptions), testing activities under Alternative 1 would involve underwater detonations and explosive practice munitions. Testing activities could be conducted in the Southern California and Hawaii Range Complexes. Testing activities using explosions do not normally occur within 3 NM of shore, with the exception of some mine warfare activities in nearshore areas of San Clemente Island. Proposed testing activities that involve explosives under Alternative 1 would differ in number and location from training activities; however, the types and severity of impacts would not be discernible from those described above in Section 3.6.3.2.2.3 (Impacts from Explosives Under Alternative 1 for Training Activities). The Navy will implement mitigation to avoid impacts from explosives on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources), which will consequently also help avoid potential impacts on fishes that shelter and feed on shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks.

As discussed previously in Section 3.6.2.1.3 (Hearing and Vocalization), all ESA-listed fish species that occur in the Study Area are capable of detecting sound and energy produced by explosives. Scalloped hammerhead sharks in the Eastern Pacific Distinct Population Segment and steelhead could be exposed to activities that involve the use of explosives within the Southern California Range Complex. However, occurrence of scalloped hammerhead sharks in Southern California is limited due to their preference for warm water temperatures. Scalloped hammerhead sharks are transient and if they do occur in the Southern California Range Complex, it would only be during times of the year when water temperatures increase or during unusually warm years (e.g., El Nino). In addition, adult steelhead may only be exposed for limited periods of time throughout the year in nearshore and offshore areas, depending on seasonality and type of spawning migration (winter-run versus summer-run) back into rivers. Giant manta rays and oceanic whitetip sharks may be exposed throughout the offshore portions of the Study Area. Gulf grouper are demersal reef fish and live close to the seafloor therefore would not be exposed to explosive activities.

Impacts on ESA-listed fishes, if they occur, would be similar to impacts on fishes in general. However, due to the short-term, infrequent and localized nature of these activities, ESA-listed fishes are unlikely to be exposed multiple times within a short period. In addition, physiological and behavioral reactions would be expected to be brief (seconds to minutes) and infrequent based on the low probability of co-occurrence between training activities and these species. Although individual individuals may be impacted, long-term consequences for populations would not be expected.

As discussed in the Section 3.6.2.2.2.1 (Status and Management), the majority of the designated physical and biological features (sites for spawning, sites for juvenile rearing, and sites for migration) for steelhead critical habitat occur in freshwater and estuaries, and do not occur within the offshore marine habitats of the Study Area. Therefore, the proposed training activities would not affect the critical habitat.

Pursuant to the ESA, the use of explosives during testing activities as described under Alternative 1 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.2.2.4 Impacts from Explosives Under Alternative 2

Impacts from Explosives Under Alternative 2 for Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Section 3.0.3.3.2 (Explosive Stressors), and Appendix A (Navy Activity Descriptions), training activities under Alternative 2 would be almost identical to those described under Alternative 1. The differences in the number of activities across a year is nominal with only slight increases in activities in the Southern California Range Complex and across a 5-year period; therefore, the locations, types, and severity of predicted impacts would not be discernible from those described above in Section 3.6.3.2.2.3 (Impacts from Explosives Under Alternative 1 for Training Activities).

Pursuant to the ESA, the use of explosives during training activities as described under Alternative 2 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks.

Impacts from Explosives Under Alternative 2 for Testing Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), testing activities under Alternative 2 include activities that produce sound and energy from explosives. Testing activities under Alternative 2 would be almost identical to those described under Alternative 1. The differences in the number of activities within each range complex across a year is nominal with only slight increases in activities in the Southern California and Hawaii Range Complexes across a 5-year period; therefore, the locations, types, and severity of predicted impacts would not be discernible from those described above for Section 3.6.3.2.2.3 (Impacts from Explosives Under Alternative 1 for Testing Activities).

Pursuant to the ESA, the use of explosives during testing activities as described under Alternative 2 would have no effect on designated critical habitat for steelhead and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of the scalloped hammerhead shark, steelhead, giant manta rays and oceanic whitetip sharks.

3.6.3.2.2.5 Impacts from Explosives Under the No Action Alternative

Impacts from Explosives under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various explosive stressors (e.g., explosive shock wave and sound; explosive fragments) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment either would remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.3 Energy Stressors

This section analyzes the potential impacts of energy stressors that can occur during training and testing activities within the Study Area. This section includes analysis of the potential impacts from (1) in-water and in-air electromagnetic devices and (2) high-energy lasers.

3.6.3.3.1 Impacts from In-Water Electromagnetic Devices

Several different in-water electromagnetic devices are used during training and testing activities. A discussion of the characteristics of energy introduced into the water through naval training and testing activities and the relative magnitude and location of these activities is presented in Section 3.0.3.3.3.1 (In-Water Electromagnetic Devices), while Table B-1 (Appendix B, Activity Stressor Matrices) lists the activities in each alternative that use the devices.

A comprehensive review of information regarding the sensitivity of marine organisms to electric and magnetic impulses is presented in Bureau of Ocean Energy Management (2011). The synthesis of available data and information contained in this report suggests that while many fish species (particularly elasmobranchs) are sensitive to electromagnetic fields (Hore, 2012), further investigation is necessary to understand the physiological response and magnitude of the potential impacts. Most examinations of electromagnetic fields on marine fishes have focused on buried undersea cables associated with offshore wind farms in European waters (Boehlert & Gill, 2010; Gill, 2005; Ohman et al., 2007).

Many fish groups, including lampreys, elasmobranchs, eels, salmonids, and stargazers, have an acute sensitivity to electrical fields, known as electroreception (Bullock et al., 1983; Helfman et al., 2009). Fishes likely use the same sensory organs (e.g., lateral line system particularly around the head) for electroreception and also for detecting sounds. Some species of sharks, such as the scalloped hammerhead, have small pores near the nostrils, around the head, and on the underside of the snout, or rostrum called ampullae of Lorenzini to detect the electromagnetic signature of their prey. Electroreceptors are thought to aid in navigation, orientation, and migration of sharks and rays (Kalmijn, 2000). In elasmobranchs, behavioral and physiological response to electromagnetic stimulus varies by species and age, and appears to be related to foraging behavior (Rigg et al., 2009). Many elasmobranchs respond physiologically to electric fields of 10 nanovolts per centimeter (cm) and behaviorally at 5 nanovolts per cm (Collin & Whitehead, 2004), while Kajiura & Holland (2002) showed juvenile scalloped hammerhead sharks detected and behaviorally responded to electric fields of less than 1 nanovolt per cm.

There are two general types of electroreceptor organs in fishes (Helfman et al., 2009). Ampullary receptors, located in recesses in the skin, are connected to the surface by a canal filled with a conductive gel and are sensitive to electric fields of low frequency (<0.1–25 Hz). Tuberous receptors are located in depressions of the epidermis, are covered with loosely packed epithelial cells, and detect higher frequency electric fields (50 Hz to > 2 kHz). They are typically found in fishes that use electric organs to produce their own electric fields. The distribution of electroreceptors on the head of these fishes, especially around the mouth, suggests that these sensory organs may be used in foraging. Additionally, some researchers hypothesize that the electroreceptors aid in social communication (Collin & Whitehead, 2004).

While elasmobranchs and other fishes can sense the level of the earth's electromagnetic field, the potential impacts on fishes resulting from changes in the strength or orientation of the background field are not well understood. When the electromagnetic field is enhanced or altered, sensitive fishes may experience an interruption or disturbance in normal sensory perception. Research on the electrosensitivity of sharks indicates that some species respond to electrical impulses with an apparent avoidance reaction (Helfman et al., 2009; Kalmijn, 2000). This avoidance response has been exploited as a shark deterrent, to repel sharks from areas of overlap with human activity (Marcotte & Lowe, 2008). A recent study on cat sharks (*Scyliorhinus canicula*) demonstrated that sharks may show habituation to electrical fields over short-term exposures (Kimber et al., 2014). Other studies suggest that sharks are attracted to electromagnetic sources when conditions in the water hinder their other senses, such as sight and hearing. This attraction to electromagnetic sources helps sharks to find prey when in these low sensory conditions (Fields, 2007).

The mechanism for direct sensing of magnetic fields is unknown; however, the presence of magnetite (a magnetic mineral) in the tissues of some fishes such as tunas and salmon, or other sensory systems such as the inner ear and the lateral line system, may be responsible for electromagnetic reception (Helfman et al., 2009). Magnetite of biogenic origins has been documented in the lateral line of the European eel (*Anguilla anguilla*) (Moore & Riley, 2009). Some species of salmon, tuna, and stargazers have likewise been shown to respond to magnetic fields and may also contain magnetite in their tissues (Helfman et al., 2009).

Experiments with electromagnetic pulses can provide indirect evidence of the range of sensitivity of fishes to similar stimuli. Two studies reported that exposure to electromagnetic pulses do not have any effect on fishes (Hartwell et al., 1991; Nemeth & Hocutt, 1990). The observed 48-hour mortality of small estuarine fishes (e.g., sheepshead minnow, mummichog, Atlantic menhaden, striped bass, Atlantic silverside, fourspine stickleback, and rainwater killifish) exposed to electromagnetic pulses of 100–200 kilovolts per m (10 nanoseconds per pulse) from distances greater than 50 m was not statistically different than the control group (Hartwell et al., 1991; Nemeth & Hocutt, 1990). During a study of Atlantic menhaden, there were no statistical differences in swimming speed and direction (toward or away from the electromagnetic pulse source) between a group of individuals exposed to electromagnetic pulses and the control group (Hartwell et al., 1991; Nemeth & Hocutt, 1990).

Electromagnetic sensitivity in some marine fishes (e.g., salmonids) is already well developed at early life stages (Ohman et al., 2007); however, most of the limited research that has occurred focuses on adults. A laboratory study on Atlantic salmon showed no behavioral changes for adults and post-smolts passing through an area with a 50 Hz magnetic field activated (Armstrong et al., 2015). Some species appear to be attracted to undersea cables, while others show avoidance (Ohman et al., 2007). Under controlled laboratory conditions, the scalloped hammerhead (*Sphyrna lewini*) and sandbar shark (*Carcharhinus plumbeus*) exhibited altered swimming and feeding behaviors in response to very weak electric fields (less than 1 nanovolt per cm) (Kajiura & Holland, 2002). In a test of sensitivity to fixed magnets, five Pacific sharks were shown to react to magnetic field strengths of 2,500–234,000 microtesla at distances ranging between 0.26 and 0.58 m and avoid the area (Rigg et al., 2009). A field trial in the Florida Keys demonstrated that southern stingrays (*Dasyatis americana*) and nurse sharks (*Ginglymostoma cirratum*) detected and avoided a fixed magnetic field producing a flux of 95,000 microtesla (O'Connell et al., 2010). A field study on white sharks (*Carcharodon carcharias*) in South Africa suggested behavioral changes in the sharks when approaching a towed prey item with an active electromagnetic field (Huveneers et al., 2013). No change was noticed in the sharks' behavior towards a static prey item. The maximum electromagnetic fields typically generated during Navy training and testing activities is approximately 2,300 microtesla.

Potential impacts of electromagnetic activity on adult fishes may not be relevant to early life stages (eggs, larvae, juveniles) due to ontogenic (life stage-based) shifts in habitat utilization (Botsford et al., 2009; Sabates et al., 2007). Some skates and rays produce egg cases that occur on the bottom, while many neonate and adult sharks occur in the water column or near the water surface. Exposure of eggs and larvae (ichthyoplankton) to electromagnetic fields would be low since their distributions are extremely patchy. Early life history stages of ESA-listed steelhead occur in freshwater or estuarine habitats outside of the Study Area. For many sharks, skates, rays, and livebearers, the fecundity and natural mortality rates are much lower, and the exposure of the larger neonates and juveniles to electromagnetic energy would be similar across life stages for these species.

Based on current literature, only the fish groups identified above are capable of detecting electromagnetic fields (primarily elasmobranchs, salmonids, tuna, eels, and stargazers) and thus will be carried forward in this section. The remaining major fish groups (from Table 3.6-2) will not be presented further. Aspects of electromagnetic stressors that are applicable to marine organisms in general are described in Section 3.0.3.6.2 (Conceptual Framework for Assessing Effects from Energy-Producing Activities).

3.6.3.3.1.1 Impacts from In-Water Electromagnetic Devices Under Alternative 1

<u>Impacts from In-Water Electromagnetic Devices Under Alternative 1 for Training Activities</u>

As indicated in Section 3.0.3.3.3.1 (In-Water Electromagnetic Devices), training activities involving in-water electromagnetic devices under Alternative 1 occur in the Hawaii and southern California Range Complexes. Table 3.0-13 shows the number and location of activities that include the use of in-water electromagnetic devices. Exposure of fishes to electromagnetic stressors is limited to those fish groups identified in the Affected Environment section above that are able to detect the electromagnetic properties in the water column (Bullock et al., 1983; Helfman et al., 2009). Species that do occur within the areas listed above, including the ESA-listed steelhead, scalloped hammerhead, and gulf grouper would have the potential to be exposed to the in-water electromagnetic devices.

In-water electromagnetic devices are used primarily during mine neutralization activities, and in most cases, the devices simply mimic the electromagnetic signature of a vessel passing through the water.

None of the devices include any type of electromagnetic “pulse.” The towed body used for mine sweeping is designed to simulate a ship’s electromagnetic signal in the water, and so would not be experienced by fishes as anything unusual. The static magnetic field generated by the electromagnetic systems is of relatively minute strength, typically 2,300 microtesla at the cable surface and 0. 2 microtesla at a radius of 200 m. The strength of the electromagnetic field decreases quickly away from the cable down to the level of earth’s magnetic field (50 microtesla) at less than 4 m from the source (U.S. Department of the Navy, 2005). In addition, training activities generally occur offshore in the water column, where fishes with high mobility predominate and fish densities are relatively low, compared with nearshore benthic habitat. Because the towed body is continuously moving, most fishes are expected to move away from it or follow behind it, in ways similar to responses to a vessel.

For any electromagnetically sensitive fishes in close proximity to the source, the generation of electromagnetic fields during training activities has the potential to interfere with prey detection and navigation. They may also experience temporary disturbance of normal sensory perception or could experience avoidance reactions (Fields, 2007; Kalmijn, 2000), resulting in alterations of behavior and avoidance of normal foraging areas or migration routes. Mortality from in-water electromagnetic devices is not expected.

ESA-listed fish species, including the Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, gulf grouper, oceanic whitetip sharks, and giant manta rays are capable of detecting electromagnetic energy and occur in the area where electromagnetic training activities are planned. Steelhead and gulf groupers generally occur in shallow nearshore and coastal waters, and therefore could encounter in-water electromagnetic devices used in training activities in the Southern California Range Complex. Other locations of electromagnetic training activities include offshore areas that overlap with the normal distribution of scalloped hammerhead sharks.

Primary constituent elements, the physical and biological features required by steelhead, are freshwater and estuary spawning, rearing, and migratory corridors. Since these features, such as freshwater and estuarine habitats, are outside the Study Area, electromagnetic stressors would have no effect on steelhead critical habitat. If located in the immediate area where in-water electromagnetic devices are being used, steelhead, gulf groupers, and scalloped hammerhead sharks could experience temporary disturbance in normal sensory perception, avoidance, or attraction reactions (Fields, 2007; Kalmijn, 2000). The generation of electromagnetic fields during training activities also has the potential to interfere with prey detection and navigation in scalloped hammerhead sharks, but any disturbance would be inconsequential.

The in-water electromagnetic devices used in training activities would not be anticipated to result in more than minimal impact on fishes as individuals or populations because (1) the range of impact (i.e., greater than earth’s magnetic field) is small (0.2 microtesla at 200 m from the source), (2) the electromagnetic components of these activities are limited to simulating the electromagnetic signature of a vessel as it passes through the water, and (3) the electromagnetic signal is temporally variable and would cover only a small spatial range during each activity in the Study Area. Some fishes could have a detectable response to electromagnetic exposure, but the fields generated are typically well below physiological and behavioral responses of magnetoreceptive fishes, and any impacts would be temporary with no anticipated impact on an individual’s growth, survival, annual reproductive success, or lifetime reproductive success (i.e., fitness), or species recruitment, and are not expected to result in population-level impacts. Electromagnetic exposure of eggs and larvae of sensitive bony fishes would be low relative to their total ichthyoplankton biomass (Able & Fahay, 1998) and; therefore, potential impacts on recruitment would not be expected.

Pursuant to the ESA, the use of in-water electromagnetic devices during training activities as described under Alternative 1 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from In-Water Electromagnetic Devices Under Alternative 1 for Testing Activities

As indicated in Section 3.0.3.3.3.1 (In-Water Electromagnetic Devices), testing activities involving in-water electromagnetic devices occur in the Hawaii and Southern California Range Complexes. Table 3.0-13 shows the number and location of activities that include the use of in-water electromagnetic devices.

For any electromagnetically sensitive fishes in close proximity to the source, the generation of electromagnetic fields during testing activities has the potential to interfere with prey detection and navigation. They may also experience temporary disturbance of normal sensory perception or could experience avoidance reactions (Kalmijn, 2000), resulting in alterations of behavior and avoidance of normal foraging areas or migration routes. Mortality from in-water electromagnetic devices is not expected.

As discussed for training activities, ESA-listed fish species, such as the Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, gulf grouper, oceanic whitetip sharks, and giant manta rays are capable of detecting electromagnetic energy and all potentially occur in the area where electromagnetic testing activities are planned. Steelhead and gulf grouper generally occur in shallow nearshore and coastal waters, and therefore could encounter in-water electromagnetic devices used in testing activities in the Southern California Range Complex. Other locations of electromagnetic testing activities include offshore areas that overlap with the normal distribution of scalloped hammerhead sharks. As discussed for training activities, activities involving electromagnetic stressors would have no effect on steelhead critical habitat. If located in the immediate area where in-water electromagnetic devices are being used, steelhead, gulf grouper, and scalloped hammerhead sharks could experience temporary disturbance in normal sensory perception or avoidance reactions. These activities also have the potential to interfere with prey detection and navigation in some species such as scalloped hammerhead sharks. Behavioral changes are not expected to have lasting effects on the survival, growth, recruitment, or reproduction of any fish species including ESA-listed species.

The in-water electromagnetic devices used in testing activities would not cause any risk to fish because of the (1) relatively low intensity of the magnetic fields generated (0.2 microtesla at 200 m from the source), (2) highly localized potential impact area, and (3) limited and temporally distinct duration of the activities (hours). Fishes may have a detectable response to electromagnetic exposure but would likely recover completely. Potential impacts of exposure to electromagnetic stressors are not expected to result in substantial changes to an individual's behavior, fitness, or species recruitment, and are not expected to result in population-level impacts.

Pursuant to the ESA, the use of in-water electromagnetic devices during testing activities, as described under Alternative 1, would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.3.1.2 Impacts from In-Water Electromagnetic Devices Under Alternative 2

Impacts from In-Water Electromagnetic Devices Under Alternative 2 for Training Activities

Because the locations, number of events, and potential effects associated with in-water electromagnetic devices would be the same under Alternatives 1 and 2, impacts experienced by fishes from in-water electromagnetic devices use under Alternative 2 would be the same as those described under Alternative 1. Therefore, impacts associated with training activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of in-water electromagnetic devices during training activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

Impacts from In-Water Electromagnetic Devices Under Alternative 2 for Testing Activities

Because the locations, number of events, and potential effects associated with in-water electromagnetic devices would be the same under Alternatives 1 and 2, impacts experienced by fishes from in-water electromagnetic devices use under Alternative 2 would be the same as those described under Alternative 1. Therefore, impacts associated with testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of in-water electromagnetic devices during testing activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

3.6.3.3.1.3 Impacts from In-Water Electromagnetic Devices under the No Action Alternative

Impacts from In-Water Electromagnetic Devices Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Electromagnetic fields from towed devices or unmanned mine warfare systems would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.3.2 Impacts from In-Air Electromagnetic Devices

In-air electromagnetic stressors are not applicable to fishes because they are transmitted in the air and not underwater and will not be analyzed further in this section.

3.6.3.3.3 Impacts from High-Energy Lasers

This section analyzes the potential impacts of high-energy lasers on fishes. As discussed in Section 3.0.3.3.3.3 (Lasers), high-energy laser weapons are designed to disable surface targets, rendering them immobile. The primary impact from high-energy lasers would be from the laser beam striking the fish at or near the water's surface, which could result in injury or death.

Fish could be exposed to a laser only if the beam missed the target. Should the laser strike the sea surface, individual fish at or near the surface could be exposed. The potential for exposure to a high-energy laser beam decreases as the water depth increases. Most fish are unlikely to be exposed to laser activities because they primarily occur more than a few meters below the sea surface.

3.6.3.3.3.1 Impacts from High-Energy Lasers Under Alternative 1

Impacts from High-Energy Lasers Under Alternative 1 for Training Activities

As indicated in Section 3.0.3.3.3.3 (Lasers), high-energy lasers would not be used during training activities under Alternative 1.

Impacts from High-Energy Lasers Under Alternative 1 for Testing Activities

Under Alternative 1, high-energy laser weapons would be used for testing activities in the HSTT Study Area.

Fish species, including some ESA-listed species such as oceanic whitetip sharks and giant mantas that are found in offshore locations and occur near the surface of the water column may pose a higher risk of being exposed to high-energy lasers. However, it is very unlikely that an individual would surface at the exact moment in the exact place that the laser hit the surface. Fishes are unlikely to be exposed to high-energy lasers based on (1) the relatively low number of events, (2) the very localized potential impact area of the laser beam, and (3) the temporary duration of potential impact (seconds). High-energy laser weapons tests would not overlap with designated critical habitat for steelhead.

Pursuant to the ESA, the use of high-energy lasers during testing activities, as described under Alternative 1, would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays. and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.3.3.2 Impacts from High-Energy Lasers under Alternative 2

Impacts from High-Energy Lasers Under Alternative 2 for Training Activities

High-energy lasers would not be used during training activities Under Alternative 2.

Impacts from High-Energy Lasers Under Alternative 2 for Testing Activities

Since the number of activities under Alternative 2 occur at the same rate and frequency relative to Alternative 1, impacts experienced by fishes from high-energy laser use under Alternative 2 would be the same as those described under Alternative 1. Therefore, impacts associated with training activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of high-energy lasers during testing activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

3.6.3.3.3.3 Impacts from High-Energy Lasers Under the No Action Alternative

Impacts from High-Energy Lasers under No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. High-energy lasers would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.4 Physical Disturbance and Strike Stressors

This section analyzes the potential impacts of the various types of physical disturbance and potential for strike during training and testing activities within the Study Area from (1) vessels; (2) in-water devices; (3) military expended materials, including non-explosive practice munitions and fragments from high-explosive munitions; and (4) seafloor devices. General discussion of impacts can also be found in Section 3.0.3.6.3 (Conceptual Framework for Assessing Effects from Physical Disturbance or Strike).

How a physical strike impacts a fish depends on the relative size of the object potentially striking the fish and the location of the fish in the water column. Before being struck by an object, salmon for example, would sense a pressure wave through the water (Hawkins & Johnstone, 1978) and have the ability to swim away from the oncoming object. The movement generated by a large object moving through the water would simply displace small fishes in open water, such as anchovies and sardines. Some fish might have time to detect the approaching object and swim away; others could be struck before they become aware of the object. An open-ocean fish that is displaced a small distance by movements from an object falling into the water nearby would likely continue on its original path as if nothing had happened. However, a bottom-dwelling fish near a sinking object would likely be disturbed, and may exhibit a general stress response, as described in Section 3.0.3.6 (Biological Resource Methods). As in all vertebrates, the function of the stress response in fishes is to rapidly alter blood chemistry levels or ratios to prepare the fish to flee or fight (Helfman et al., 2009). This generally adaptive physiological response can become a liability to the fish if the stressor persists and the fish is not able to return to its baseline physiological state. When stressors are chronic, the fish may experience reduced growth, health, or survival (Wedemeyer et al., 1990). If the object hits the fish, direct injury (in addition to stress) or death may result.

The potential responses to a physical strike are varied, but include behavioral changes such as avoidance, altered swimming speed and direction, physiological stress, and physical injury or mortality. Despite their ability to detect approaching vessels using a combination of sensory cues (e.g., sight, hearing, and lateral line), larger slow-moving fishes (e.g., whale sharks [*Rhincodon typus*], basking sharks [*Cetorhinus maximus*], manta rays [*Manta* spp.), and ocean sunfish) cannot avoid all collisions, with some collisions resulting in mortality (Braun et al., 2015; Couturier et al., 2012; Deakos et al., 2011; Foderaro, 2015; Germanov & Marshall, 2014; Graham et al., 2012; Miller & Klimovich, 2016; Ramirez-Macias et al., 2012; Rowat et al., 2007; Speed et al., 2008; Stevens, 2007). Many fishes respond by darting quickly away from the stimulus. Some other species may respond by freezing in place and adopting cryptic coloration, while still some other species may respond in an unpredictable manner. Regardless of the response, the individual must stop its current activity and divert its physiological and cognitive attention to responding to the stressor (Helfman et al., 2009). The energy costs of reacting to a stressor depend on the specific situation, but in all cases the caloric requirements of stress reactions reduce the amount of energy available to the fish for other functions, such as predator avoidance, reproduction, growth, and maintenance (Wedemeyer et al., 1990).

The ability of a fish to return to its previous activity following a physical strike (or near-miss resulting in a stress response) is a function of a variety of factors. Some fish species are more tolerant of stressors than others and become re-acclimated more easily. Within a species, the rate at which an individual recovers from a physical strike may be influenced by its age, sex, reproductive state, and general condition. A fish that has reacted to a sudden disturbance by swimming at burst speed would tire after only a few minutes; its blood hormone and sugar levels (cortisol and glucose) may not return to normal for up to, or longer than, 24 hours. During its recovery period, the fish would not be able to attain burst speeds and would be more vulnerable to predators (Wardle, 1986). If the individual were not able to regain a steady state following exposure to a physical stressor, it may suffer reduced immune function and even death (Wedemeyer et al., 1990).

Potential impacts of physical disturbance or strike to adults may be different than for other life stages (e.g., eggs, larvae, juveniles) because these life stages do not necessarily occur together in the same location (Botsford et al., 2009; Sabates et al., 2007), and because they have different response capabilities. The numbers of eggs and larvae exposed to vessel movements would be low relative to total ichthyoplankton biomass (Able & Fahay, 1998); therefore, measurable effects on fish recruitment would not be expected. Also, the early life stages of most marine fishes (excluding sharks and other livebearers) already have extremely high natural mortality rates (10–85 percent per day) from predation on these life stages (Helfman et al., 2009), and therefore, most eggs and larvae are not expected to survive to the next life stage (Horst, 1977).

3.6.3.4.1 Impacts from Vessels and In-Water Devices

Representative Navy vessel types, lengths, and speeds of vessels used in the Study Area is presented in Table 3.0-15. The number and location of activities for each Alternative is presented in Table 3.0-16, while Table B-1 in Appendix B (Activity Stressor Matrices) lists the activities in each alternative that use the devices.

Vessels do not normally collide with adult fishes, most of which can detect and avoid them. One study on Barents Sea capelin (*Mallotus villosus*) behavioral responses to vessels showed that most adults exhibit avoidance responses to engine noise, sonar, depth finders, and fish finders (Jørgensen et al., 2004), reducing the potential for vessel strikes. Misund (1997) found that fishes, such as polar cod (*Boreogadus saida*), haddock (*Melanogrammus aeglefinus*), jack mackerel (*Trachurus symmetricus*), sardine (*Sardina pilchardus*), herring, anchovy (*Engraulis ringens*), and capelin, that were ahead of a ship showed avoidance reactions and did so at ranges of 50–350 m. When the vessel passed over them, some fishes responded with sudden avoidance responses that included lateral avoidance or downward compression of the school. Conversely, Rostad, (2006) observed that some fishes are attracted to different types of vessels (e.g., research vessels, commercial vessels) of varying sizes, noise levels, and habitat locations. Fishes involved in that study included herring (*Clupea harengus*), sprat (*Sprattus sprattus*), and whitefish (*Merlangius merlangu*s) (Rostad et al., 2006). Fish behavior in the vicinity of a vessel is therefore quite variable, depending on the type of fish, its life history stage, behavior, time of day, and the sound propagation characteristics of the water (Schwartz, 1985). Early life stages of most fishes could be displaced by vessels and not struck in the same manner as adults of larger species. However, a vessel's propeller movement or propeller wash could entrain early life stages. The low-frequency sounds of large vessels or accelerating small vessels caused avoidance responses among herring (Chapman & Hawkins, 1973), but avoidance ended within 10 seconds after the vessel departed.

There are a few notable exceptions to this assessment of potential vessel strike impacts on fish groups. Large slow-moving fishes such as whale sharks (Ramirez-Macias et al., 2012; Rowat et al., 2007; Speed et al., 2008; Stevens, 2007), basking sharks (Pacific Shark Research Center, 2017; The Shark Trust, 2017), and manta rays (Braun et al., 2015; Couturier et al., 2012; Deakos et al., 2011; Germanov & Marshall, 2014; Graham et al., 2012; Miller & Klimovich, 2016) may occur near the surface in open-ocean and coastal areas, thus making them more susceptible to ship strikes which may result in blunt trauma, lacerations, fin damage, or mortality. Stevens (2007) noted that increases in the numbers and sizes of shipping vessels in the modern cargo fleets make it difficult to gather strike-related mortality data for whale sharks because personnel on large ships are often unaware of collisions; therefore, the occurrence of vessel strikes is likely much higher than has been documented by the few studies that have been conducted. This holds true not just for whale sharks, but also for any of the aforementioned fish species.

Based on the typical physiological responses described in Section 3.6.3.4 (Physical Disturbance and Strike Stressors), vessel movements are not expected to compromise the general health or condition of individual fishes, except for large slow-moving fishes such as whale sharks, basking sharks, manta rays, and ocean sunfish (Foderaro, 2015; Rowat et al., 2007; Speed et al., 2008; Stevens, 2007).

In-water devices do not normally collide with adult fishes, as most can detect and avoid them. Fish responses to in-water devices would be similar to those discussed above for vessels. Fishes would likely show varying behavioral avoidance responses to in-water devices. Early life stages of most fishes could be displaced by in-water devices and not struck in the same manner as adults of larger species. Because in-water devices are continuously moving, most fishes are expected to move away from them or to follow behind them.

3.6.3.4.1.1 Impacts from Vessels and In-Water Devices Under Alternative 1

Impacts from Vessels and In-Water Devices Under Alternative 1 for Training Activities

Section 3.0.3.3.4.1 (Vessels and In-Water Devices) provide estimates of relative vessel and in-water device use and location for each of the alternatives. These estimates are based on the number of activities predicted for each alternative. While these estimates predict use, actual Navy vessel usage depends on military training and testing requirements, deployment schedules, annual budgets, and other unpredictable factors. Training concentrations mostly depends on locations of Navy shore installations and established training areas. The Navy's use of these areas has not appreciably changed in the last decade and are not expected to change in the reasonably foreseeable future. Under Alternative 1, the concentration of vessel use and the manner in which the Navy trains would remain consistent with the range of variability observed over the last decade. As underwater technologies advance, it is likely that the frequency of in-water devise use may increase. However, the Navy does not foresee any appreciable changes in the locations where in-water devices have been used over the last decade, and therefore the level at which strikes are expected to occur is likely to remain consistent with the previous decade.

Navy training vessel traffic would primarily occur within the U.S. Exclusive Economic Zone, and certain portions of the Study Area, such as areas near ports or naval installations and ranges (e.g., Pearl Harbor, San Diego, San Diego Bay, and San Clemente Island) are used more heavily by vessels than other portions of the Study Area. These activities do not differ seasonally and could be widely dispersed throughout the Study Area. Species that do not occur near the surface within the Study Area would not be exposed to vessel or in-water device strike potential.

The risk of a strike from vessels and in-water devices such as a remotely operated vehicles, unmanned surface vehicles, unmanned underwater vehicles, motorized autonomous targets, or towed mine warfare devices used in training activities would be low because (1) most fishes can detect and avoid vessel and in-water device movements and (2) the types of fish that are likely to be exposed to vessel and in-water device strikes are limited (such as whale sharks and manta rays) and occur in low concentrations where vessels and in-water devices are most frequently used. Potential impacts from exposure to vessels and in-water devices are not expected to result in substantial changes to an individual's behavior, fitness, or species recruitment, and are not expected to result in population-level impacts. In addition, best management practices would be implemented prior to deploying a towed in-water device to search the intended path of the in-water device for any floating debris (e.g., driftwood) or other potential obstructions (e.g., floating vegetation rafts and animals), since they have the potential to cause damage to the device. Therefore, the device would not be used in areas where pelagic (open ocean) fish naturally aggregate.

Based on the distribution of steelhead, gulf grouper, and the overlap of vessel use, potential strike risk would be greatest in the coastal areas of the Southern California Range Complex. Similar to other fish species, steelhead can sense pressure changes in the water column and swim quickly (Baum, 1997; Popper & Hastings, 2009b), and are likely to escape collision with vessels. However, since vessels could overlap with steelhead, there would be the potential for effect from disturbance. The majority of the physical and biological features required by steelhead are applicable to freshwater and estuaries (i.e., spawning sites, rearing sites, and migration corridors), and are outside the Study Area. Gulf grouper are bottom dwelling and unlikely to be impacted by vessels on the surface of the water.

The potential risk of a vessel or in-water device strike to a scalloped hammerhead shark would be extremely low, but possible in the surface waters where this species can be observed swimming. As a vessel approaches, and individual could have a detectable behavioral or physiological response (e.g., swimming away and increased heart rate) as the passing vessel displaces them. However, scalloped hammerhead sharks would be able to detect and avoid vessel movements and would return to their normal behavior after the ship or device passes. Since vessels and in-water device training could overlap with scalloped hammerhead shark habitat, there would be the potential for effect from disturbance.

Giant manta rays in offshore areas may be susceptible to vessel strikes in those areas, as are the closely related reef manta ray (Braun et al., 2015; Couturier et al., 2012; Deakos et al., 2011; Germanov & Marshall, 2014; Graham et al., 2012; Miller & Klimovich, 2016). However, unlike the reef manta ray, the giant manta ray is typically found in low numbers, rarely aggregates, and would be able to hear an approaching vessel and avoid a potential strike.

As described above, the use of vessels and in-water devices may result in short-term and local displacement of fish in the water column. However, these behavioral reactions are not expected to result in substantial changes to an individual's fitness, or species recruitment, and are not expected to result in population-level impacts. Ichthyoplankton (fish eggs and larvae) in the water column could be displaced, injured, or killed by towed mine warfare devices. The numbers of eggs and larvae exposed to vessels or in-water devices would be extremely low relative to total ichthyoplankton biomass (Able & Fahay, 1998); therefore, measurable changes on fish recruitment would not occur.

The majority of the physical and biological features required by steelhead are applicable to freshwater and estuaries (i.e., spawning sites, rearing sites, and migration corridors), and are outside the Study Area. Therefore, in-water device use would not affect steelhead critical habitat.

Pursuant to the ESA, the use of vessels and in-water devices during training activities, as described under Alternative 1, would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from Vessels and In-Water Devices Under Alternative 1 for Testing Activities

As indicated in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), most of the testing activities involve vessel movements. However, the number of activities that include the vessel movement for testing is comparatively lower than the number of training activities. In addition, testing often occurs jointly with a training event, so it is likely that the testing activity would be conducted from a training vessel. Vessel movement in conjunction with testing activities could be widely dispersed throughout the Study Area, but would be concentrated near naval ports, piers, range complexes, testing ranges. Testing activities involving the use of vessels and in-water devices would also occur in the HSTT Study Area at any time of year. Under Alternative 1, testing activities involving the use of vessels and in-water devices would be conducted throughout the HSTT Study Area, including the same areas where vessel movement is occurring.

As previously discussed, with the exception of some large, slow-moving species that may occur at the surface, the risk of a strike from a vessel or in-water devices used in testing activities would be extremely low because most fishes can detect and avoid in-water device movements, and exposure to vessels. In addition, in-water devices are not expected to result in substantial changes to an individual's behavior, fitness, or species recruitment, and are not expected to result in population-level impacts. There is also no overlap of the vessels and in-water device use with designated critical habitat for steelhead.

Pursuant to the ESA, the use of vessels and in-water devices during testing activities as described under Alternative 1 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.4.1.2 Impacts from Vessels and In-Water Devices Under Alternative 2

Impacts from Vessels Under Alternative 2 for Training Activities

Because training activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, physical disturbance and strike stress experienced by fishes from vessels and in-water device use under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with training and testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of vessels and in-water devices during training activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

Impacts from Vessels and In-Water Devices under Alternative 2 for Testing Activities

Because testing activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, physical disturbance and strike stress experienced by fishes from vessels and in-water device use under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with training and testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of vessels and in-water devices during testing activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

3.6.3.4.1.3 Impacts from Vessels and In-Water Devices Under the No Action Alternative

Impacts from Vessels Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various physical strike stressors to fishes from vessels or in-water devices would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.4.2 Impacts from Aircraft and Aerial Targets

Aircraft and aerial targets stressors are not applicable to fishes because they are conducted in the air and not underwater and will not be analyzed further in this section.

3.6.3.4.3 Impacts from Military Expended Materials

Navy training and testing activities in the Study Area include firing a variety of weapons and employing a variety of explosive and non-explosive rounds including bombs; small-, medium-, and large-caliber projectiles; or sinking exercises with ship hulks. During these training and testing activities, various items may be introduced and expended into the marine environment and are referred to as military expended materials.

This section analyzes the disturbance or strike potential to fish of the following categories of military expended materials: (1) non-explosive practice munitions, (2) fragments from high-explosive munitions, and (3) expended materials other than munitions, such as sonobuoys, ship hulks, and expendable targets. Section 3.0.3.3.4.2 (Military Expended Materials) provides information on the quantity and location where activities would occur under each alternative. Appendix F (Military Expended Material and Direct Strike Impact Analyses) provides additional information on each military expended material proposed to be used, where it would be used, how many would be used, and the amount of area impacted by each device. Analysis of all potential impacts (disturbance, strike) of military expended materials on critical habitat is included in this section.

While disturbance or strike from any of these objects as they sink through the water column is possible, it is not very likely for most expended materials because the objects generally sink through the water slowly and can be avoided by most, if not all fishes. Therefore, with the exception of sinking exercises, the discussion of military expended materials strikes focuses on strikes at the surface or in the upper water column from fragments (of high-explosives) and projectiles because those items have a greater potential for a fish strike as they hit the water, before slowing down as they move through the water column.

Ship Hulk. During a sinking exercise, aircraft, ship, and submarine crews fire or drop munitions on a seaborne target, usually a clean deactivated ship (Section 3.2, Sediments and Water Quality), which is deliberately sunk using multiple weapon systems. A description of sinking exercises is presented in Appendix A (Navy Activity Descriptions). Sinking exercises occur in specific open ocean areas, outside of the coastal range complexes, in waters exceeding 3,000 m (9,842.5 ft.) in depth. Direct munitions strikes from the various weapons used in these exercises are a source of potential impact. However, these impacts are discussed for each of those weapons categories in this section and are not repeated in the respective sections. Therefore, the analysis of sinking exercises as a strike potential for benthic fishes is discussed in terms of the ship hulk landing on the seafloor.

Small-, Medium-, and Large-Caliber Projectiles. Various types of projectiles could cause a temporary (seconds), localized impact when they strike the surface of the water. Current Navy training and testing in the Study Area, such as gunnery exercises and testing events, include firing a variety of weapons and using a variety of non-explosive training and testing rounds, including 5-inch naval gun shells, and small-, medium-, and large-caliber projectiles. The larger-caliber projectiles are primarily used in the open ocean beyond 20 NM. Direct munitions strikes from firing weapons are potential stressors to fishes. There is a remote possibility that an individual fish at or near the surface may be struck directly if it is at the point of impact at the time of non-explosive munitions delivery. Expended rounds may strike the water surface with sufficient force to cause injury or mortality. However, limited fish species swim right at, or near, the surface of the water (e.g., with the exception of pelagic sharks, herring, salmonids, flyingfishes, jacks, tuna, mackerels, billfishes, ocean sunfishes, and other similar species).

Various projectiles would fall on soft or hard bottom habitats, where they could either become buried immediately in the sediments, or sit on the bottom for an extended time period. Most munitions would sink through the water column and come to rest on the seafloor, stirring up sediment and possibly inducing an alarm response, displacing, or injuring nearby fishes in extremely rare cases. Particular impacts on a given fish species would depend on the size and speed of the munitions, the water depth, the number of rounds delivered, the frequency of training and testing, and the sensitivity of the fish (U.S. Department of the Navy, 2013).

Bombs, Missiles, and Rockets. Direct munitions strikes from bombs, missiles, and rockets are potential stressors to fishes. Some individual fish at or near the surface may be struck directly if they are at the point of impact at the time of non-explosive munitions delivery. However, most missiles hit their target or are disabled before hitting the water. Thus, most of these missiles hit the water as fragments, which quickly dissipates their kinetic energy within a short distance of the surface. A limited number of fishes swim right at, or near, the surface of the water, as described for small-, medium-, and large-caliber projectiles.

Even though statistical modeling conducted for the Study Area (discussed in Appendix F, Military Expended Materials and Direct Strike Impact Analyses) indicates that the probability of military expended materials striking marine mammals or sea turtles is extremely low, modeling could not be conducted to estimate the probability of military expended material strikes on an individual fish. This is primarily due to the lack of fish density data available at the scale of a range complex or testing range.

In lieu of strike probability modeling, the number, size, and area of potential impact (or “footprints”) of each type of military expended material is presented in Appendix F (Military Expended Material and Direct Strike Impact Analyses). The application of this type of footprint analysis to fish follows the notion that a fish occupying the impact area could be susceptible to potential impacts, either at the water surface (e.g., pelagic sharks, salmonids, flyingfishes, jacks, tunas, mackerels, billfishes, and ocean sunfishes [Table 3.6-2]) or as military expended material falls through the water column and settles to the bottom (e.g., flounders, skates, and other benthic fishes listed in Table 3.6-2). Furthermore, most of the projectiles fired during training and testing activities are fired at targets, and most projectiles hit those targets, so only a very small portion of those would hit the water with their maximum velocity and force. Of that small portion, a small number of fish at or near the surface (pelagic fishes) or near the bottom (benthic fishes) may be directly impacted if they are in the target area and near the expended item that hits the water surface (or bottom).

Propelled fragments are produced by an exploding bomb. Close to the explosion, fishes could potentially sustain injury or death from propelled fragments (Stuhmiller et al., 1991). However, studies of underwater bomb blasts have shown that fragments are large and decelerate rapidly (O'Keeffe & Young, 1984; Swisdak & Montanaro, 1992), posing little risk to marine organisms.

Fish disturbance or strike could result from bomb fragments (after explosion) falling through the water column in very small areas compared to the vast expanse of the testing ranges, range complexes, or the remainder of the Study Area. The expected reaction of fishes exposed to military expended materials would be to immediately leave the area where bombing is occurring, thereby reducing the probability of a fish strike after the initial expended materials hit the water surface. When a disturbance of this type concludes, the area would be repopulated and the fish stock would rebound, with inconsequential impacts on the resource (Lundquist et al., 2010).

3.6.3.4.3.1 Impacts from Military Expended Materials Under Alternative 1

Impacts from Military Expended Materials Under Alternative 1 for Training Activities

As stated above, Section 3.0.3.3.4.2 (Military Expended Materials) provides information on the number and location where training activities would occur under each alternative, while Appendix F (Military Expended Material and Direct Strike Impact Analyses) has more information on where the military expended material would be used, how many would be used, and the amount of area impacted by each device.

Major fish groups identified in Table 3.6-2 that are particularly susceptible to military expended material strikes are those occurring at the surface, within the offshore and continental shelf portions of the range complexes (where the strike would occur). Those groups include salmonids, pelagic sharks, flyingfishes, jacks, tunas, mackerels, billfishes, ocean sunfishes, and other similar species (Table 3.6-2). Additionally, certain deep-sea fishes would be exposed to strike risk as a ship hulk, expended during a sinking exercise, settles to the seafloor. These groups include hagfishes, dragonfishes, lanternfishes, anglerfishes, and oarfishes.

Projectiles, bombs, missiles, rockets, and associated fragments have the potential to directly strike fish as they hit the water surface and below the surface to the point where the projectile loses its forward momentum. Fishes at and just below the surface would be most susceptible to injury from strikes because velocity of these materials would rapidly decrease upon contact with the water and as they travel through the water column. Consequently, most water column fishes would have ample time to detect and avoid approaching munitions or fragments as they fall through the water column. The probability of strike based on the “footprint” analysis included in Section 3.5 (Habitats) indicates that even for an extreme case of expending all small-caliber projectiles within a single gunnery box, the probability of any of these items striking a fish (even as large as bluefin tuna or whale sharks) is extremely low. Therefore, since most fishes are smaller than bluefin tuna or whale sharks, and most military expended materials are less abundant than small-caliber projectiles, the risk of strike by these items is exceedingly low for fishes overall. A possibility exists that a small number of fish at or near the surface may be directly impacted if they are in the target area and near the point of physical impact at the time of military expended material strike, but population-level impacts would not occur.

Sinking exercises occur in open-ocean areas, outside of the coastal range complexes. While serious injury or mortality to individual fish would be expected if they were present within range of high explosive activities (analyzed in Section 3.6.3.1, Acoustic Stressors), sinking exercises would not result in impacts on pelagic fish populations at the surface based on the low number of fish in the immediate area and the placement of these activities in deep, ocean areas where fish abundance is low or widely dispersed. Also, these activities are very few in number. Disturbances to benthic fishes from sinking exercises would be highly localized. Any deep-sea fishes located on the bottom where a ship hulk would settle could experience displacement, injury, or death. However, population-level impacts on the deep sea fish community would not occur because of the limited spatial extent of the impact and the wide dispersal of fishes in deep ocean areas.

All of the ESA-listed fish species occurring in training areas would be potentially exposed to military expended materials. While military expended materials use could overlap with steelhead, gulf groupers, and scalloped hammerhead sharks, the likelihood of a strike would be extremely low given the low abundance of steelhead, gulf grouper, and scalloped hammerhead sharks in the Study Area and the dispersed nature of the activity.

There is no overlap of military expended materials use with designated critical habitat for steelhead. The majority of the physical and biological features required by steelhead are applicable to freshwater and estuaries (i.e., spawning sites, rearing sites, and migration corridors), and are outside the Study Area. Therefore, military expended materials use would not affect steelhead critical habitat.

The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks) to avoid potential impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). The mitigation will consequently help avoid potential impacts on fishes that inhabit shallow-water coral reefs and precious coral beds.

The impact of military expended material strikes on fishes would be inconsequential due to (1) the limited number of species found directly at the surface where military expended material strikes could occur, (2) the rare chance that a fish might be directly struck at the surface by military expended materials, and, (3) the ability of most fishes to detect and avoid an object falling through the water below the surface. The potential impacts of military expended material strikes would be short-term (seconds) and localized disturbances of the water surface (and seafloor areas within sinking exercise boxes) and are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction at the population level.

Pursuant to the ESA, military expended material from training activities as described under Alternative 1 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from Military Expended Materials Under Alternative 1 for Testing Activities

Appendix F (Military Expended Materials and Direct Strike Impact Analyses) has more information on the type and quantities of military expended materials proposed to be used. The quantity of military expended material during testing activities would be substantially less than training activities described above.

Potential impacts from military expended material strikes on marine fish groups and ESA-listed species during testing activities would be similar to those described for comparable training activities. Military expended materials hitting the water could result in an extremely unlikely strike of an individual fish, or more likely in a short-term and local displacement of fish in the water column. However, these behavioral reactions are not expected to result in substantial changes to an individual's fitness or species recruitment, and are not expected to result in population-level impacts.

As discussed under the training activities analysis for impacts from military expended materials under Alternative 1, military expended materials use could overlap with steelhead, gulf grouper, and scalloped hammerhead sharks. However, the likelihood of a strike would be extremely low given the low abundance of steelhead and scalloped hammerhead sharks in the Study Area and the dispersed nature of the activity. The majority of the physical and biological features required by steelhead are applicable to freshwater and estuaries and are outside of the Study Area. Therefore, military expended materials (e.g., decelerators/parachutes, guidance wires, and fiber optic cables) would not be expended within steelhead critical habitat and would not affect steelhead.

The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks) to avoid potential impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area (Section 5.4.1, Mitigation Areas for Seafloor Resources). The mitigation will consequently help avoid potential impacts on fishes that inhabit shallow-water coral reefs and precious coral beds.

The impact of military expended material strikes would be inconsequential due to (1) the limited number of species found directly at the surface where military expended material strikes could occur, (2) the rare chance that a fish might be directly struck at the surface by military expended materials, and (3) the ability of most fish to detect and avoid an object falling through the water below the surface. The potential impacts of military expended material strikes would range from short-term (seconds) and localized disturbances of the water surface and long-term impacts for individuals if struck. However these impacts are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction at the population level.

Pursuant to the ESA, military expended material from testing activities as described under Alternative 1 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.4.3.2 Impacts from Military Expended Materials Under Alternative 2

<u>Impacts from Military Expended Materials Under Alternative 2 for Training Activities</u>

Because training activities under Alternative 2 occur at the same rate and frequency relative to Alternative 1, physical disturbance and strike stress experienced by fishes from military expended materials under Alternative 2 would be the same as those described under Alternative 1. Therefore, impacts associated with training and testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, military expended material from training activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

Impacts from Military Expended Materials Under Alternative 2 for Testing Activities

Because testing activities under Alternative 2 would occur at the same rate and frequency relative to Alternative 1, physical disturbance and strike stress experienced by fishes from military expended materials under Alternative 2 would be the same as those described under Alternative 1. Therefore, impacts associated with training and testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, military expended material from testing activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

3.6.3.4.3.3 Impacts from Military Expended Materials Under the No Action Alternative

Impacts from Military Expended Materials Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Various military expended materials stressors for fishes would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.4.4 Impacts from Seafloor Devices

The number and location of activities including seafloor devices is presented in Section 3.0.3.3.4.3 (Seafloor Devices). Additional information on stressors by testing and training activity is provided in Appendix B (Activity Stressor Matrices). Seafloor devices include items that are placed on, dropped on, or moved along the seafloor such as mine shapes, anchor blocks, anchors, bottom-placed instruments, bottom-crawling unmanned underwater vehicles, and bottom-placed targets that are not expended. As discussed in the military expended materials strike section, objects falling through the water column would slow in velocity as they sink toward the bottom and could be avoided by most, if not all fish.

Aircraft deployed mine shapes, anchor blocks, anchors, and bottom-placed instruments, and targets all have the potential to strike fish upon deployment as they sink through the water column and settle on the seafloor. Unmanned underwater vehicles (e.g., bottom crawl vehicles) also have the potential to strike a fish. Some fishes are attracted to virtually any tethered object in the water column for food or refuge (Dempster & Taquet, 2004) and could be attracted to a non-explosive mine assembly. However, while a fish might be attracted to the object, its sensory abilities allow it to avoid colliding with fixed tethered objects in the water column (Bleckmann & Zelick, 2009), so the likelihood of a fish striking one of these objects is implausible. Therefore, strike hazards associated with collision into other seafloor devices such as deployed mine shapes or anchored devices are highly unlikely to pose any strike hazard to fishes and are not discussed further.

3.6.3.4.4.1 Impacts from Seafloor Devices under Alternative 1

Impacts from Seafloor Devices Under Alternative 1 for Training Activities

Table 3.0-27 shows the number and location of activities that use seafloor devices. As indicated in Section 3.0.3.3.4.3 (Seafloor Devices), activities that use seafloor devices occur in Hawaii and Southern California Range Complexes.

Aircraft-deployed mine shapes which are deployed at the surface during aerial mine laying training activities have the greatest potential to strike a fish within the water column. While seafloor device use could overlap with steelhead, gulf grouper, and scalloped hammerhead distributions, the likelihood of a strike would be extremely low given the low abundance of these ESA-listed species recorded in the Study Area, the ability for these species to detect and avoid falling objects through the water below the surface, and the dispersed nature of the activity. However, there would be the potential for effect.

In addition, seafloor devices are not anticipated to affect any physical and biological features of critical habitat for steelhead (i.e., spawning sites, rearing sites, and migration corridors), and are outside the Study Area. Therefore, seafloor device use would not affect steelhead critical habitat.

The Navy will implement mitigation that includes not conducting precision anchoring (except in designated anchorages) within the anchor swing circle of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks to avoid potential impacts from seafloor devices on seafloor resources in mitigation areas throughout the Study Area (Section 5.4.1, Mitigation Areas for Seafloor Resources). This mitigation will consequently help avoid potential impacts on fishes that inhabit these areas.

Pursuant to the ESA, the use of seafloor devices during training activities as described under Alternative 1 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from Seafloor Devices Under Alternative 1 for Testing Activities

As described above for training activities, Table 3.0-27 provides the number and location of activities that use seafloor devices in Hawaii and Southern California Range Complexes. Military expended materials falling through the water column, such as aircraft deployed mine shapes, will slow in velocity as they sink toward the bottom and would be avoided by most fishes. The impacts on ESA-listed species are identical to non-explosive practice bombs discussed in the analysis of potential impacts in the military expended material strike section. These devices would not be used where ESA-listed steelhead, scalloped hammerhead sharks, or Gulf grouper occur. Similarly, these devices are not anticipated to affect any physical and biological features of critical habitat for any of these species.

Pursuant to the ESA, the use of seafloor devices during testing activities as described under Alternative 1 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.4.4.2 Impacts from Seafloor Devices under Alternative 2

Impacts from Seafloor Devices Under Alternative 2 for Training Activities

Because training activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, physical disturbance and strike stress experienced by fishes from seafloor device use under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with training activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of seafloor devices during training activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the

ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

Impacts from Seafloor Devices Under Alternative 2 for Testing Activities

Because testing activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, physical disturbance and strike stress experienced by fishes from seafloor device use under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of seafloor devices during testing activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

3.6.3.4.4.3 Impacts from Seafloor Devices Under the No Action Alternative

Impacts from Seafloor Devices Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Stressors for fishes such as seafloor devices would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.4.5 Impacts from Pile Driving

Physical disturbance and strike stressors from pile driving activities are not applicable to fishes because they are mobile and would be able to avoid the stressors and will not be analyzed further in this section.

3.6.3.5 Entanglement Stressors

This section evaluates potential entanglement impacts of various types of expended materials used by the Navy during training and testing activities within the Study Area. The likelihood of fishes being affected by an entanglement stressor is a function of the physical properties, location, and buoyancy of the object and the behavior and physical features of the fish, as described in Section 3.0.3.6.4 (Conceptual Framework for Assessing Effects from Entanglement). Three types of military expended materials are considered here: (1) wires and cables (2) decelerators/parachutes, and (3) biodegradable polymer.

Most entanglement observations involve abandoned or discarded nets, lines, and other materials that form loops or incorporate rings (Derraik, 2002; Keller et al., 2010; Laist, 1987; Macfadyen et al., 2009). A 25-year dataset assembled by the Ocean Conservancy reported that fishing line, rope, and fishing nets accounted for approximately 68 percent of fish entanglements, with the remainder due to encounters with various items such as bottles, cans, and plastic bags (Ocean Conservancy, 2010b). No occurrences involving military expended materials were documented.

Fish entanglement occurs most frequently at or just below the surface or in the water column where objects are suspended. A smaller number involve objects on the seafloor, particularly abandoned fishing gear designed to catch bottom fishes or invertebrates (Ocean Conservancy, 2010b). More fish species are entangled in coastal waters and the continental shelf than elsewhere in the marine environment because of higher concentrations of human activity (e.g., fishing, sources of entangling debris), higher fish abundances, and greater species diversity (Helfman et al., 2009; Macfadyen et al., 2009). The consequences of entanglement range from temporary and inconsequential to major physiological stress or mortality.

Some fishes are more susceptible to entanglement in derelict fishing gear and other marine debris, compared to other fish groups. Physical features, such as rigid or protruding snouts of some elasmobranchs (e.g., the wide heads of hammerhead sharks), increase the risk of entanglement compared to fishes with smoother, more streamlined bodies (e.g., lamprey and eels). Most fishes, except for jawless fishes and eels that are too smooth and slippery to become entangled, are susceptible to entanglement gear specifically designed for that purpose (e.g., gillnets). As described in Section 3.0.3.3.5.3 (Biodegradable Polymer), Marine Vessel Stopping payloads are systems designed to deliver the appropriate measure(s) to affect a vessel's propulsion and associated control surfaces to significantly slow and potentially stop the advance of the vessel. Marine Vessel Stopping proposed activities include the use of biodegradable polymers designed to entangle the propellers of in-water vessels. Marine Vessel Stopping payload systems designed to entangle the propellers of small in-water vessels would only be used during testing activities, not during training (Table 3.0-32).

The overall effects of entanglement are highly variable, ranging from temporary disorientation to mortality due to predation or physical injury. The evaluation of a species' entanglement potential should consider the size, location, and buoyancy of an object as well as the size, physical characteristics, and behavior of the fish species.

The following sections seek to identify entanglement potential due to military expended material. Where appropriate, specific geographic areas (open ocean areas, range complexes, and bays and inland waters) of potential impact are identified.

3.6.3.5.1 Impacts from Wires and Cables

Fiber optic cables, guidance wires, and sonobuoys (which contain a wire) are used during training and testing activities. The number and location of items expended under each alternative is presented in Section 3.0.3.3.5.1 (Wires and Cables), with additional details provided in Appendix B (Activity Stressor Matrices).

Fish groups identified in Table 3.6-2 that could be susceptible to entanglement in expended cables and wires are those such as sawfishes, with elongated snouts lined with tooth-like structures that easily snag on other similar marine debris, such as derelict fishing gear (Macfadyen et al., 2009). Some elasmobranchs (including hammerhead sharks and manta rays) and billfishes occurring within the offshore and continental shelf portions of the range complexes and testing ranges (where the potential for entanglement would occur) could be susceptible to entanglement in cables and wires. Species occurring outside the specified areas within these range complexes would not be exposed to fiber optic cables, guidance wires, or sonobuoy wire.

Once a guidance wire is released, it is likely to sink immediately and remain on the seafloor. In some cases, the wire may snag on a hard structure near the bottom and remain partially or completely suspended. The types of fish that encounter any given wire would depend, in part, on its geographic location and vertical location in the water column. In any situation, the most likely mechanism for entanglement would involve fish swimming through loops in the wire that tighten around it; however, loops are unlikely to form in a guidance wire or sonobuoy wire because of its size and rigidity (Environmental Sciences Group, 2005).

Because of their physical characteristics, guidance wires and fiber optic cables pose a potential, though unlikely, entanglement risk to susceptible fishes. Analysis of potential entanglement for fishes is based on abandoned monofilament, nylon, and polypropylene lines used in commercial nets. Such derelict fishing gear is abundant in the ocean (Macfadyen et al., 2009) and pose a greater hazard to fishes than wires expended by the Navy. Fishing gear materials often have breaking strengths that can be up to orders of magnitude greater than that of guidance wire and fiber optic cables (Environmental Sciences Group, 2005), and are far more prone to tangling, as discussed in Section 3.0.3.3.5.1 (Wires and Cables). Fiber optic cables do not easily form loops, are brittle, and break easily if bent, so they pose a negligible entanglement risk. Additionally, the encounter rate and probability of impact from guidance wires and fiber optic cables are low, as few are expended (see Chapter 2, Description of Proposed Action and Alternatives, for further information).

Sonobuoys consist of a surface antenna and float unit and a subsurface hydrophone assembly unit. The two units are attached through a thin gauge dual conductor and hard draw copper strand wire, which is then wrapped by a hollow rubber tubing or bungee in a spiral configuration. The tensile breaking strength of the wire is a maximum of 40 lb. (Swope & McDonald, 2013). The length of the cable is housed in a plastic canister dispenser, which remains attached upon deployment. The length of wire that extends out is no more than 1,500 ft. and is dependent on the water depth and type of sonobuoy. Attached to the wire is a kite-drogue and damper disk stabilizing system made of non-woven nylon fabric. The nylon fabric is very thin and can be broken by hand. The cable runs through the stabilizing system, and leads to the hydrophone components. The hydrophone components may be covered by thin plastic netting depending on type of sonobuoy, but pose no entanglement risk. Each sonobuoy has a saltwater-activated polyurethane float that inflates when the sonobuoy is submerged and keeps the sonobuoy components floating vertically in the water column below it. Sonobuoys remain suspended in the water column for no more than 30 hours, after which they sink to the seafloor.

The sonobuoy itself is not considered an entanglement hazard for upon deployment (Environmental Sciences Group, 2005), but its components may pose an entanglement hazard once released into the ocean. Aerial-launched sonobuoys are deployed with a decelerator/parachute. Sonobuoys contain cords, electronic components, and plastic mesh that may entangle fish (Environmental Sciences Group, 2005). Open-ocean filter feeding species, such as basking sharks, whale sharks, scalloped hammerhead sharks, oceanic whitetip sharks, and manta rays could become entangled in these items, whereas smaller species could become entangled in the plastic mesh in the same manner as a small gillnet. Since most sonobuoys are expended in offshore areas, many coastal fishes would not encounter or have any opportunity to become entangled in materials associated with sonobuoys.

3.6.3.5.1.1 Impacts from Wires and Cables Under Alternative 1

Impacts from Wires and Cables Under Alternative 1 for Training Activities

As indicated in Section 3.0.3.3.5.1 (Wires and Cables), activities that expend fiber optic cables, guidance wires, and sonobuoy wires occur in both the Southern California and Hawaii Range Complexes. Fiber optic cables are comprised of silicon and are somewhat flexible, durable, and abrasion or chemical resistant. The physical characteristics of the fiber optic material render the cable easily broken when tightly kinked or bent at a sharp angle, but highly resistant to breaking when wrapped or looped around an object.(U.S. Department of the Navy, 2001a). Additionally, encounter rates with fiber optic cables are limited by the small number that are expended.

Juveniles and adults would be potentially exposed to entanglement stressors such as fiber optic cables within the Study Area. Some ESA-listed species such as scalloped hammerhead sharks and Gulf grouper could encounter fiber-optic cables because they are expended during training activities where these species are found. In addition, giant manta rays and oceanic whitetip sharks occur in offshore areas where training activities would occur. The likelihood of entanglement for these species from wires and cables expended during training activities is low because these species would be able to see and avoid cables and wires in the water column. In the rare instance where a fish did encounter a fiber optic cable, entanglement is unlikely because the cable is not strong enough to bind most fishes (U.S. Department of the Navy, 2001a).

Guidance wire would only be expended in offshore areas and not within inshore or nearshore habitats in the HSTT Study Areas. With the exception of juvenile steelhead that occur in freshwater streams outside of the Study Area, ESA-listed species, including scalloped hammerheads and gulf grouper could potentially encounter guidance wire because they can occur in nearshore waters out to the shelf break, where they often feed near the bottom and could become entangled in a guidance wire while feeding. Guidance wires sink too quickly to be transported very far before reaching the seafloor (Environmental Sciences Group, 2005). Fish would rarely encounter guidance wires expended during training activities. If a guidance wire were encountered, the most likely result would be that the fish ignores it, which is an inconsequential and considered negligible. In the rare instance where an individual fish became entangled in guidance wire and could not break free, the individual could be impacted as a result of impaired feeding, bodily injury, or increased susceptibility to predators. However, this is an extremely unlikely scenario because the density of guidance wires would be very low, as discussed in Section 3.0.3.3.5.1 (Wires and Cables).

Sonobuoy wires may be expended throughout the HSTT Study Area. As described above, a sonobuoy wire runs through the stabilizing system and leads to the hydrophone components. The hydrophone components may be covered by thin plastic netting depending on type of sonobuoy but pose no entanglement risk. This is mainly due to the sonobuoy being made of a single wire that hangs vertically in the water column. Therefore, it would be highly unlikely that a fish, including ESA-listed species, would be entangled by a sonobuoy wire.

While individual fish susceptible to entanglement could encounter guidance wires, fiber optic cables, and sonobuoy wires, the long-term consequences of entanglement are unlikely for either individuals or populations because (1) the encounter rate for cables and wires is low, (2) the types of fishes that are susceptible to these items is limited, (3) the restricted overlap with susceptible fishes, and (4) the physical characteristics of the cables and wires reduce entanglement risk to fishes compared to monofilament used for fishing gear. Potential impacts from exposure to guidance wires and fiber optic cables are not expected to result in substantial changes to an individual's behavior, fitness, or species recruitment, and are not expected to result in population-level impacts.

The sink rates of these guidance wires would rule out the possibility of it drifting great distances into nearshore and coastal areas where steelhead are found, or into designated river or estuarine critical habitat. Steelhead move quickly through nearshore to offshore areas after leaving freshwater; since their populations are so low in the Study Area (Hovey, 2004), it would be highly unlikely that they would encounter an expended guidance wire.

Pursuant to the ESA, the use of wires and cables during training activities as described under Alternative 1 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from Wires and Cables Under Alternative 1 for Testing Activities

As discussed in Section 3.0.3.3.5.1 (Wires and Cables), under Alternative 1 testing activities, fiber optic cables, guidance wires, and sonobuoy components that would pose an entanglement risk to marine fishes, including ESA-listed species, would be similar to those described training activities, even though testing activities occur at a higher frequency compared to training activities.

ESA-listed species susceptible to entanglement such as Gulf grouper and scalloped hammerhead sharks occur in testing locations, but are unlikely to encounter the guidance wires because of their low densities in the areas where they are expended.

As discussed above for training activities, long-term consequences of entanglement are unlikely for either individuals or populations because (1) the encounter rate for cables and wires is low, (2) the types of fishes that are susceptible to these items is limited, (3) the restricted overlap with susceptible fishes, and (4) the physical characteristics of the cables and wires reduce entanglement risk to fishes compared to monofilament used for fishing gear. Potential impacts from exposure to guidance wires and fiber optic cables are not expected to result in substantial changes to an individual's behavior, fitness, or species recruitment, and are not expected to result in population-level impacts.

Pursuant to the ESA, the use of wires and cables during testing activities as described under Alternative 1 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.5.1.2 Impacts from Wires and Cables Under Alternative 2

Impacts from Wires and Cables Under Alternative 2 for Training Activities

Because activities under Alternative 2 occur at the same rate and frequency relative to Alternative 1, entanglement stress experienced by fishes from fiber optic cables, guidance wires, and sonobuoy wires under Alternative 2 would be the same as those described under Alternative 1. Therefore, impacts associated with training and testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of wires and cables during training activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

Impacts from Wires and Cables Under Alternative 2 for Testing Activities

Even though testing activities under Alternative 2 occur at a slightly higher rate and frequency relative to Alternative 1, entanglement stress experienced by fishes from guidance wires, fiber optic cables, and sonobuoy wires under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of wires and cables during testing activities, as described under Alternative 2, would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the

ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

3.6.3.5.1.3 Impacts from Wires and Cables Under the No Action Alternative

Impacts from Wires and Cables Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Entanglement stressors for fishes from wires and cables would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.5.2 Impacts from Decelerators/Parachutes

Decelerators/Parachutes of varying sizes are used during training and testing activities. Section 3.0.3.3.5.2 (Decelerators/Parachutes) describes the use and platforms where decelerators/parachutes would be released into the marine environment. Table 3.0-31 presents the size categories for decelerators/parachutes expended during training and testing activities that could present an entanglement risk to fishes. The types of activities that use decelerators/parachutes, physical characteristics and size of decelerators/parachutes, locations where decelerators/parachutes are used, and the number of decelerator/parachute activities proposed under each alternative are presented in Appendix B (Activity Stressor Matrices). Fishes face many potential entanglement scenarios in abandoned monofilament, nylon, polypropylene line, and other derelict fishing gear in the nearshore and offshore marine habitats of the Study Area (Macfadyen et al., 2009; Ocean Conservancy, 2010b). Abandoned fishing gear is dangerous to fishes because it is abundant, essentially invisible, strong, and easily tangled. In contrast, decelerators/parachutes are rare, highly visible, and not designed to capture fishes. The weak entangling features reduce the risk to ESA-protected fishes.

Once a decelerator/parachute has been released to the water, it poses a potential entanglement risk to fishes. The Naval Ocean Systems Center identified the potential impacts of torpedo air launch accessories, including decelerators/parachutes, on fish (U.S. Department of the Navy, 2001a). Unlike other materials in which fish become entangled (such as gill nets and nylon fishing line), the decelerator/parachute is relatively large and visible, reducing the chance that visually oriented fish would accidentally become entangled in it. No cases of fish entanglement have been reported for decelerators/parachutes (Ocean Conservancy, 2010b; U.S. Department of the Navy, 2001b). Entanglement in a newly expended decelerator/parachute and its attachment lines while it is in the water column is unlikely because fish generally react to sound and motion at the surface with a behavioral reaction by swimming away from the source (see Section 3.6.3.4.3, Impacts from Military Expended Materials) and would detect the oncoming decelerator/parachute in time to avoid contact. While the decelerator/parachute is sinking, fish would have ample opportunity to swim away from the large moving object. Even if the decelerator/parachute landed directly on a fish, it would likely be able to swim away faster than the decelerator/parachute would sink because the resistance of the water would slow the decelerator/parachute’s downward motion.

Once the decelerator/parachute is on the bottom, however, it is feasible that a fish could become entangled in the decelerator/parachute or its attachment lines while diving and feeding, especially in deeper waters where it is dark. If the decelerator/parachute is dropped in an area of strong bottom currents, it could billow open and pose a short-term entanglement threat to large fish feeding on the bottom. Benthic fishes with elongated spines could become caught on the decelerator/parachute or lines. Most sharks and other smooth-bodied fishes are not expected to become entangled because their soft, streamlined bodies can more easily slip through potential snares. A fish with spines or protrusions (e.g., some sharks [including hammerheads], manta rays, and billfishes,) on its body that swam into the decelerator/parachute or a loop in the lines, and then struggled, could become bound tightly enough to prevent escape. Although this scenario is possible based on the structure of the materials and the shape and behavior of fishes, it is not considered a likely event.

3.6.3.5.2.1 Impacts from Decelerators/Parachutes Under Alternative 1

Impacts from Decelerators/Parachutes Under Alternative 1 for Training Activities

Fish species that could be susceptible to entanglement in decelerators/parachutes are the same as discussed for cables and wires. As discussed in Section 3.0.3.3.5.2 (Decelerators/Parachutes), training activities involving decelerator/parachute use that would pose an entanglement risk under Alternative 1 would be expended in the open ocean portions of the Study Area. Appendix F (Military Expended Materials and Direct Strike Impact Analyses) provides a list of expended materials that would include decelerators/parachutes. Table F-1 provides the number of each type of military expended material used for training activities under Alternative 1.

Given the size of the range complexes and the resulting widely scattered decelerators/parachutes, it would be very unlikely that ESA-listed steelhead, gulf groupers, giant manta rays, oceanic whitetip sharks, or scalloped hammerhead sharks would encounter and become entangled in any decelerators/parachutes or sonobuoy accessories.

Some elasmobranchs (hammerhead sharks and manta rays), swordfishes, and billfishes occurring within the offshore and continental shelf portions of the Study Area (where the potential for entanglement would occur) may be more susceptible to entanglement in decelerators/parachutes than most fish species, due primarily to their unusual body shape or projections. As described above, the highly maneuverable swimming capabilities of these fishes make it unlikely that any entanglement would occur while the decelerators/parachutes are at the surface or sinking through the water column. If an ESA-listed fish, such as a scalloped hammerhead shark, were to encounter a decelerator/parachute and become entangled, the shark would likely thrash in an effort to break free. If such an effort were unsuccessful, the individual could remain entangled, possibly resulting in injury or death. However, this scenario is considered so unlikely that it would be discountable. Oceanic whitetip sharks and giant manta rays occurring offshore could come into contact with a parachute/decelerator during training activities. This species is also a highly mobile, visual predators that could easily avoid floating or suspended decelerators/parachutes or break free if it got entangled. If a fish from one of these species were to become entangled in a decelerator/parachute, they would likely thrash in an effort to break free. If such an effort were unsuccessful, the individual could remain entangled, possibly resulting in injury or death, but this scenario is considered so unlikely that it would be discountable. Individual fish are not prone to be repeatedly exposed to decelerators/parachutes; thus the long-term consequences of entanglement risks from decelerators/parachutes are unlikely for either individuals or populations.

Pursuant to the ESA, the use of decelerators/parachutes during training activities as described under Alternative 1 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from Decelerators/Parachutes Under Alternative 1 for Testing Activities

As discussed in Section 3.0.3.3.5.2 (Decelerators/Parachutes), under Alternative 1 testing activities, decelerators/parachutes that would pose an entanglement risk to fishes would be expended in both Southern California and Hawaii Range Complexes. Appendix F (Military Expended Materials and Direct Strike Impact Analyses) provides a list of expended materials that would include decelerators/parachutes. Table F-2 provides the number of each type of military expended material used for testing activities under Alternative 1.

Based on the numbers and geographic locations of their use, decelerators/parachutes pose a risk of entanglement for all fish species that occurs in the Study Area, including ESA-listed species and would be the same as discussed for cables and wires. For the reasons stated above for the training activities analysis, impacts on ESA-listed species such as steelhead, scalloped hammerhead sharks, giant manta rays, oceanic whitetip sharks, and Gulf grouper would be discountable. Fish are unlikely to encounter or become entangled in decelerators/parachutes because of the large size of the range complexes and testing ranges and the resulting widely scattered expended decelerators/parachutes. Individual fish are not prone to be repeatedly exposed to these entanglement stressors, thus the long-term consequences of entanglement risks from decelerators/parachutes are unlikely for either individuals or populations.

Pursuant to the ESA, use of decelerators/parachutes during testing activities as described under Alternative 1 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.5.2.2 Impacts from Decelerators/Parachutes Under Alternative 2

Impacts from Decelerators/Parachutes Under Alternative 2 for Training Activities

Because training activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, entanglement stress experienced by fishes from decelerators/parachutes under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with training and testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, use of decelerators/parachutes during training activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

Impacts from Decelerators/Parachutes Under Alternative 2 for Testing Activities

Even though testing activities under Alternative 2 occur at a slightly lower rate and frequency relative to Alternative 1, entanglement stress experienced by fishes from decelerators/parachutes under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with training and testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, use of decelerators/parachutes during testing activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

3.6.3.5.2.3 Impacts from Decelerators/Parachutes Under the No Action Alternative

Impacts from Decelerators/Parachutes Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Entanglement stressors for fishes from decelerators/parachutes would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.5.3 Impacts from Biodegradable Polymer

For a discussion of the types of activities that use biodegradable polymers see Appendix B (Activity Stressor Matrices) and for a discussion on where they are used and how many activities would occur under each alternative, see Section 3.0.3.3.5.3 (Biodegradable Polymer). Navy activities that involve Marine Vessel Stopping payloads include the development of the biodegradable polymer and would be associated with testing activities in the HSTT Study Area. Marine Vessel Stopping payloads are systems designed to deliver the appropriate measure(s) to affect a vessel's propulsion and associated control surfaces to significantly slow and potentially stop the advance of the vessel. A biodegradable polymer is a high molecular weight polymer that degrades to smaller compounds as a result of microorganisms and enzymes The rate of biodegradation could vary from hours to years and the type of small molecules formed during degradation can range from complex to simple products, depending on whether the polymers are natural or synthetic (Karlsson & Albertsson, 1998). Based on the constituents of the biodegradable polymer the Navy proposes to use, it is anticipated that the material will breakdown into small pieces within a few days to weeks. This will breakdown further and dissolve into the water column within weeks to a few months. The final products which are all environmentally benign will be dispersed quickly to undetectable concentrations. Unlike other entanglement stressors, biodegradable polymers only retain their strength for a relatively short period of time; therefore the potential for entanglement by a fish would be limited. Furthermore the longer the biodegradable polymer remains in the water, the weaker it becomes making it more brittle and likely to break. A fish would have to encounter the biodegradable polymer after it was expended for it to be a potential entanglement risk. If an animal were to approach the polymer more than a few weeks after it was expended, it is very likely that it would break easily and would not be able to entangle a fish. Since biodegradable polymers are only proposed for testing activities involving Marine Vessel Stopping payload systems in the HSTT Study Area, the concentration of these items being expended in both the Hawaii Range Complex and the Southern California Range Complex in the HSTT Study Area is considered very low and the rate of encounter and risk of entanglement for fishes would be considered extremely low.

3.6.3.5.3.1 Impacts from Biodegradable Polymer Under Alternative 1

Impacts from Biodegradable Polymer Under Alternative 1 for Training Activities

Biodegradable polymers would not be used during training activities associated with the Proposed Action.

Impacts from Biodegradable Polymer Under Alternative 1 for Testing Activities

Under Alternative 1, use of biodegradable polymers during testing of Marine Vessel Stopping payload systems would conducted within the Hawaii Range Complex and the Southern California Range Complex in the HSTT Study Area. Biodegradable polymers would be expended in the greater numbers in the Southern California Range Complex.

ESA-listed species such as steelhead, and gulf grouper may occur in the Southern California portion of the HSTT Study Area, while scalloped hammerhead sharks, giant manta rays, and oceanic whitetip sharks occur primarily in the Hawaii portions of the HSTT Study Area. These species may be exposed to the biodegradable polymer during Marine Vessel Stopping payload system testing. However, the likelihood of a fish encountering the biodegradable polymers when they are first expended is low because polymers are brittle and only remain intact for relatively short periods of time (days to weeks).

Pursuant to the ESA, the use of biodegradable polymer during Marine Vessel Stopping payload system testing activities, as described under Alternative 1, would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.5.3.2 Impacts from Biodegradable Polymer Under Alternative 2

Impacts from Biodegradable Polymer Under Alternative 2 for Training Activities

Biodegradable polymers would not be used during training activities associated with the Proposed Action.

Impacts from Biodegradable Polymer Under Alternative 2 for Testing Activities

Marine Vessel Stopping payload system testing activities that expend biodegradable polymers under Alternative 2 would be the same as what is proposed under Alternative 1. The analysis presented above in Section 3.6.3.5.3.1 (Impacts from Biodegradable Polymer Under Alternative 1) for testing activities would also apply to Alternative 2.

Pursuant to the ESA, use of biodegradable polymer during Marine Vessel Stopping payload system testing activities, as described under Alternative 2, would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead giant manta rays, and oceanic whitetip sharks.

3.6.3.5.3.3 Impacts from Biodegradable Polymer Under the No Action Alternative

Impacts from Biodegradable Polymer Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. The use of biodegradable polymer during testing of Marine Vessel Stopping payload systems is not a part of ongoing Navy activities in the Study Area, and this entanglement stressor would not be introduced into the marine environment under the No Action Alternative. Therefore, no change in baseline conditions of the existing environment would occur.

3.6.3.6 Ingestion Stressors

This section analyzes the potential ingestion impacts of the various types of munitions and military expended materials other than munitions used by the Navy during training and testing activities within the Study Area. Aspects of ingestion stressors that are applicable to marine organisms in general are presented in Section 3.0.3.6.5 (Conceptual Framework for Assessing Effects from Ingestion). Ingestion of expended materials by fishes could occur in coastal and open ocean areas, and can occur at or just below the surface, in the water column, or at the seafloor depending on the size and buoyancy of the expended object and the feeding behavior of the fish. Floating material is more likely to be eaten by fishes that feed at or near the water surface (e.g., ocean sunfish, basking sharks, manta rays, or flyingfishes), while materials that sink to the seafloor present a higher risk to bottom-feeding fishes (e.g., rockfishes, hammerhead sharks, skates, and flatfishes).

It is reasonable to assume that any item of a size that can be swallowed by a fish could be eaten at some time; this analysis focuses on ingestion of materials in two locations: (1) at the surface or water column and (2) at the seafloor. The potential for fish, including the ESA-listed fish species, to encounter and ingest expended materials is evaluated with respect to their feeding group and geographic range, which influence the probability that they would eat military expended materials.

The Navy expends the following types of materials during training and testing in the Study Area that could become ingestion stressors: non-explosive practice munitions (small- and medium-caliber), fragments from high-explosives, fragments from targets, chaff, flare casings (including plastic end caps and pistons), small decelerators/parachutes and biodegradable polymer. The location and number of activities that expend these items are detailed in Section 3.0.3.3.6 (Ingestion Stressors) and in Appendix B (Activity Stressor Matrices). Metal items eaten by fish are generally small (such as fishhooks, bottle caps, and metal springs), suggesting that small- and medium-caliber projectiles, pistons, or end caps (from chaff canisters or flares) are more likely to be ingested. Both physical and toxicological impacts could occur as a result of consuming metal or plastic materials (Dantas et al., 2012; Davison & Asch, 2011; Possatto et al., 2011). Ingestion of plastics has been shown to increase hazardous chemicals in fish leading to liver toxicity of fishes (Rochman et al., 2013). Items of concern are those of ingestible size that either drift at or just below the surface (or in the water column) for a time or sink immediately to the seafloor. The likelihood that expended items would cause a potential impact on a given fish species depends on the size and feeding habits of the fish and the rate at which the fish encounters the item and the composition of the item. In this analysis only small- and medium-caliber munitions (or small fragments from larger munitions), chaff, small decelerators/parachutes, and end caps and pistons from flares and chaff cartridges are considered to be of ingestible size for a fish. For many small fish species (e.g., anchovy, sardines, etc.), even these items (with the exception of chaff) are often too large to be ingested, even though small pieces could sometimes be nibbled off by small fishes. Therefore, the discussion in this section focuses on those fish species large enough to potentially ingest these materials.

The analysis of ingestion impacts on fishes is structured around the following feeding strategies:

Feeding at or Just Below the Surface or Within the Water Column

- **Open-Ocean Predators.** Large, migratory, open-ocean fishes, such as tunas, mahi mahi, sharks, and billfishes, feed on fast-swimming prey in the water column of the Study Area. These fishes range widely in search of unevenly distributed food patches. Smaller military expended materials could be mistaken for prey items and ingested purposefully or incidentally as the fish is swimming (Table 3.6-17). A few of these predatory fishes (e.g., tiger sharks) are known to ingest any type of marine debris that they can swallow, even automobile tires. Some marine fishes, such as tunas, eat plastic fragments, strings, nylon lines, ropes, or even small light bulbs (Choy & Drazen, 2013; Rochman et al., 2015).

- **Open-Ocean Planktivores.** Plankton-eating fishes in the open-ocean portion of the Study Area include anchovies, sardines, flyingfishes, ocean sunfish, manta rays, whale sharks, and basking sharks. These fishes feed by either filtering plankton from the water column or by selectively ingesting larger zooplankton. These planktivores could encounter and incidentally feed on smaller types of military expended materials (e.g., chaff, end caps, pistons) at the surface or in the water column (Table 3.6-17). Giant manta rays are the only ESA-listed species in the Study Area that is an open ocean planktivore, while some species in this group of fishes (e.g., anchovies) constitute a major prey base for many important predators, including tunas, sharks, marine mammals, and seabirds. While not a consumer of plankton, the ocean sunfish eats jellyfish and may consume a decelerator/parachute by accident at or just below the surface in the open ocean. Larger filter feeders such as whale sharks, basking sharks, and manta rays could also inadvertently ingest a decelerator/parachute.

Military expended materials that could potentially impact these types of fish at or just below the surface or in the water column include those items that float or are suspended in the water column for some period of time (e.g., decelerators/parachutes and end caps and pistons from chaff cartridges or flares).

Fishes Feeding at the Seafloor

- **Bottom Dwelling Predators.** Large predatory fishes near the seafloor are represented by rockfishes, groupers, and jacks, which are typical seafloor predators in the Study Area (Table 3.6-17). These species feed opportunistically on or near the bottom, taking fish and invertebrates from the water column and from the bottom (e.g., crabs, octopus). Bottom-dwelling fishes in the nearshore coasts (see Table 3.6-17) may feed by seeking prey and by scavenging on dead fishes and invertebrates (e.g., skates, rays, flatfishes, ratfishes).
- **Bottom Dwelling Foragers and Scavengers**. Bottom dwelling fishes may feed by seeking prey and by scavenging on dead fishes and invertebrates. Flatfishes, rays, and some sharks in the Study Area feed along the bottom on small fish and invertebrate prey, which could increase the likelihood of incidental ingestion of marine debris.

Military expended materials that could be ingested by fishes at the seafloor include items that sink (e.g., small-caliber projectiles and casings, fragments from high-explosive munitions).

Potential impacts of ingestion on some adult fishes are different than for other life stages (eggs, larvae, and juveniles) because early life stages for some species are too small to ingest any military expended materials except for chaff, which has been shown to have limited effects on fishes in the concentration levels that it is released at (Arfsten et al., 2002; U.S. Department of the Air Force, 1997; U.S. Department of the Navy, 1999). Therefore, with the exception of later stage larvae and juveniles that could ingest microplastics, no ingestion potential impacts on early life stages are expected.

Within the context of fish location in the water column and feeding strategies, the analysis is divided into (1) munitions (small- and medium-caliber projectiles, and small fragments from larger munitions); and (2) military expended material other than munitions (chaff, chaff end caps, pistons, decelerators/parachutes, flares, and target fragments).

3.6.3.6.1 Impacts from Military Expended Materials – Munitions

Different types of explosive and non-explosive practice munitions are expended at sea during training and testing activities. This section analyzes the potential for fishes to ingest non-explosive practice munitions and fragments from high explosive munitions.

Types of non-explosive practice munitions generally include projectiles, missiles, and bombs. Of these, only small- or medium-caliber projectiles would be small enough for a large fish to ingest. Small- and medium-caliber projectiles include all sizes up to and including 2.25 inches in diameter. These solid metal materials would quickly move through the water column and settle to the seafloor. Ingestion of non-explosive practice munitions in the water column is possible when shiny fragments of the munitions sink quickly and could be ingested by fast, mobile predators that chase moving prey (e.g., tunas, jacks, billfishes, swordfishes, dolphinfishes, mackerel, wahoo, and barracudas). In addition, these fragments may also be accidentally ingested by fishes that forage on the bottom such as flatfishes, skates, and rays.

Table 3.6-17: Ingestion Stressors Potential for Impact on Fishes Based on Location

Feeding Guild	Representative Species	ESA-Protected Species	Overall Potential for Impact
Open-ocean Predators	Mahi mahi, most shark species, tunas, billfishes. swordfishes	Scalloped hammerhead sharks, Oceanic (adult) steelhead, Oceanic whitetip sharks	These fishes may eat floating or sinking expended materials, but the encounter rate would be extremely low. May result in individual injury or death but is not anticipated to have population-level effects.
Open-ocean consumer of plankton	Basking sharks, whale sharks	Giant manta rays	These fishes may ingest floating expended materials incidentally as they feed in the water column, but the encounter rate would be extremely low. May result in individual injury or death but is not anticipated to have population-level effects.
Coastal bottom-dwelling predators	Rockfishes, groupers, jacks	Oceanic (adult) steelhead, Gulf grouper	These fishes may eat expended materials on the seafloor, but the encounter rate would be extremely low. May result in individual injury or death but is not anticipated to have population-level effects.
Coastal/estuarine bottom-dwelling predators and scavengers	Skates and rays, flatfishes	None	These fishes could incidentally eat some expended materials while foraging, especially in muddy waters with limited visibility. May result in individual injury or death but is not anticipated to have population-level effects.

Note: The scientific name of the listed species is as follows: basking shark (*Cetorhinus maximus*), mahi mahi (*Coryphaena hippurus*), tunas (*Thunn*us species), billfishes (Xiphiidae), scalloped hammerhead shark (*Sphyrna lewini*), rockfishes (*Sebastes* species), jacks (Carangidae), skates (Rajidae), rays (Batoidea), and flatfishes (Paralichthyida*e*).

Types of high explosive munitions that can result in fragments include demolition charges, projectiles, missiles, and bombs. Fragments would result from fractures in the munitions casing and would vary in size depending on the size of the net explosive weight and munitions type; however, typical sizes of fragments are unknown. These solid metal materials would quickly move through the water column and settle to the seafloor. Similar to non-explosive practice munitions described above, ingestion of high-explosive munition fragments by fast-moving mobile predators such tunas, jacks, billfishes, swordfishes, dolphinfishes, mackerel, wahoo, and barracudas in the water column is possible. In the unlikely event that explosive material, high-melting-point explosive (known as HMX), or royal demolition explosive (known as RDX) is exposed on the ocean floor, it would break down in a few hours (U.S. Department of the Navy, 2001a, 2001c). High-melting-point explosive or royal demolition explosive would not accumulate in the tissues of fish (Lotufo et al., 2010; Price et al., 1998). Fragments are primarily encountered by species that forage on the bottom.

It is possible that expended small-caliber projectiles on the seafloor could be colonized by seafloor organisms and mistaken for prey or that expended small-caliber projectiles could be accidentally or intentionally eaten during foraging. Over time, the metal may corrode or become covered by sediment in some habitats, reducing the likelihood of a fish encountering the small caliber, non-explosive practice munitions.

The potential impacts of ingesting foreign objects on a given fish depend on the species and size of the fish. Fish that normally eat spiny, hard-bodied invertebrates may have tougher mouths and digestive systems than fish that normally feed on softer prey. Materials that are similar to the normal diet of a fish would be more likely to be ingested and more easily handled once ingested—for example, by fishes that feed on invertebrates with sharp appendages. These items could include fragments from high-explosives that a fish could encounter on the seafloor. Relatively small or smooth objects, such as small caliber projectiles or their casings, might pass through the digestive tract without causing harm. A small sharp-edged item could cause a fish immediate physical distress by tearing or cutting the mouth, throat, or stomach. If the object is rigid and large (relative to the fish's mouth and throat), it may block the throat or obstruct the flow of waste through the digestive system. An object may be enclosed by a cyst in the gut lining (Danner et al., 2009; Hoss & Settle, 1990). Ingestion of large foreign objects could lead to disruption of a fish's normal feeding behavior, which could be sublethal or lethal.

3.6.3.6.1.1 Impacts from Military Expended Materials – Munitions Under Alternative 1

Impacts from Military Expended Materials – Munitions Under Alternative 1 for Training Activities

As indicated in Section 3.0.3.3.6.1 (Non-Explosive Practice Munitions), small- and medium-caliber projectile use would occur throughout the Study Area. Species that occur in these areas would have the potential to be exposed to small- and medium-caliber projectiles. As indicated in Section 3.0.3.3.6.2 (Fragments from High-Explosive Munitions), high-explosive munitions and munitions use may occur throughout the Study Area. When these items explode, they may break apart or remain largely intact in irregularly shaped pieces—some of which may be small enough for some fishes to ingest. ESA-listed species such as scalloped hammerhead sharks may be exposed to fragments in the offshore locations where small-caliber projectile use is concentrated. However it would be unlikely to ingest small-caliber projectiles that are sinking through the water column in the scalloped hammerhead sharks habitat. Training activities expending projectiles or munitions could expose other ESA-listed species such as Gulf grouper to ingestion risk. A grouper could be injured if it ingested a small-caliber projectile or fragment and couldn't pass it. However, it is more likely that only small fragments of the munitions would be accidentally consumed compared to an entire casing.

The potential impacts of ingesting small-caliber projectiles, high explosive fragments, or end caps/pistons would be limited to individual cases where a fish might suffer a negative response, for example, ingesting an item too large to be digested. While ingestion of munitions-related materials, or the other military expended materials identified here, could result in sublethal or lethal impacts, the likelihood of ingestion is low based on the dispersed nature of the materials and the limited exposure of those items at the surface/water column or seafloor where certain fishes could be at risk of ingesting those items. Furthermore, a fish might taste an item then expel it before swallowing it (Felix et al., 1995), in the same manner that fish would temporarily take a lure into its mouth, then spit it out. Based on these factors, the number of fish potentially impacted by ingestion of munitions-related materials would be low and population-level impacts are not likely to occur.

As indicated in Section 3.0.3.3.6.3 (Military Expended Materials Other Than Munitions), activities that expend chaff and flares occur in the open ocean areas of the Hawaii and Southern California Range Complexes. Species that occur in these areas would have the potential to be exposed to chaff and flares. No potential impacts would occur from the chaff itself, as discussed in Section 3.0.3.3.6.3 (Military Expended Materials Other Than Munitions), but there is some potential for the end caps or pistons associated with the chaff cartridges to be ingested. The flare device consists of a cylindrical cartridge approximately 1.4 in (3.6 cm) in diameter and 5.8 in (14.7 cm) in length. Items that could be potentially ingested from flares include plastic end caps and pistons.

Large, open-ocean predators (e.g., tunas, billfishes, pelagic sharks), including ESA-listed scalloped hammerhead sharks, have the potential to ingest self-protection flare end caps or pistons as they float on the water column for some time. A variety of plastic and other solid materials have been recovered from the stomachs of billfishes, dorado (South Atlantic Fishery Management Council, 2011) and tuna (Hoss & Settle, 1990). An extensive literature review and controlled experiments conducted by the U.S. Air Force determined that self-protection flare use poses little risk to the environment (U.S. Department of the Air Force, 1997).

While munitions use could overlap with steelhead, gulf grouper, and scalloped hammerhead sharks, the likelihood of ingestion would be extremely low given the low abundance of ESA species in the Study Area and the dispersed nature of the activity. However, there would be the potential for effect. The majority of the physical and biological features required by steelhead are applicable to freshwater and estuaries (i.e., spawning sites, rearing sites, and migration corridors), and are outside the Study Area. Therefore, munitions use would not affect steelhead critical habitat. The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs and precious coral beds) to avoid potential impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area (Section 5.4.1, Mitigation Areas for Seafloor Resources). This mitigation will consequently help avoid potential impacts on fishes that feed on shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks.

Overall, the potential impacts of ingesting munitions (whole or fragments) would be limited to individual fish that might suffer a negative response from a given ingestion event. While ingestion of munitions or fragments identified here could result in sublethal or lethal effects to a small number of individuals, the likelihood of a fish encountering an expended item is dependent on where that species feeds and the amount of material expended. Furthermore, an encounter may not lead to ingestion, as a fish might "taste" an item, then expel it (Felix et al., 1995), in the same manner that a fish would take a lure into its mouth then spit it out. Therefore, the number of fishes potentially impacted by ingestion of munitions or fragments from munitions would be assumed to be low, and population-level effects would not be expected.

Pursuant to the ESA, the use of military expended materials - munitions during training activities as described under Alternative 1 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from Military Expended Materials – Munitions Under Alternative 1 for Testing Activities

Use of military expended materials from munitions may occur throughout the HSTT Study Area. Fish in the vicinity of these activities would have the potential to ingest military expended materials (small caliber projectiles, and medium caliber projectiles) from munitions.

When these items explode, they may break apart or remain largely intact in irregularly shaped pieces—some of which may be small enough for a fish to ingest. Some fish species feed on crustaceans that have hard, sharp, or irregular parts, without any impacts. Most fragments from high-explosives would be too large for a fish to ingest. Also, it is assumed that fragments from larger munitions are similar in size to fragments from smaller munitions. Although fragment size cannot be quantified, more individual fragments would result from larger munitions than from smaller munitions. The number of fragments that would result from the proposed explosions cannot be quantified. However, it is believed to be smaller than the number of small and medium -caliber projectiles to be expended in the Study Area. Small- and medium-caliber projectiles would likely be more prevalent throughout the Study Area and more likely to be encountered and potentially ingested by bottom-dwelling fish than fragments from any type of high-explosive munitions. Furthermore, a fish might taste an item then expel it before swallowing it (Felix et al., 1995), in the same manner that fish would temporarily take a lure into its mouth, then spit it out. Based on these factors, the number of fish potentially impacted by ingestion of munitions would be low and population-level impacts are not likely to occur.

While munitions use could overlap with steelhead, gulf grouper, and scalloped hammerhead sharks, the likelihood of ingestion would be extremely low given the low abundance of ESA species in the Study Area and the dispersed nature of the activity. The majority of the physical and biological features required by steelhead are applicable to freshwater and estuaries (i.e., spawning sites, rearing sites, and migration corridors), and are outside the Study Area. Therefore, munitions use would not affect steelhead critical habitat. The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs and precious coral beds) to avoid potential impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area (Section 5.4.1, Mitigation Areas for Seafloor Resources). This mitigation will consequently help avoid potential impacts on fishes that feed on shallow-water coral reefs and precious coral beds.

As described above for training activities, giant manta rays and oceanic whitetip sharks are generally surface-oriented feeders. It is unlikely that these species would mistake larger military expended materials in the water column for prey, but if this occurred they accidentally ingested military expended materials, it is likely that they would "taste" the item and then expel it because these species would be able to distinguish between food and non-food items.

Overall, the impacts on fishes ingesting munitions or fragments from munitions resulting from proposed testing activities would be low. The number of fishes potentially impacted by ingestion of munitions or fragments from munitions would be low, and population-level effects would not be expected.

Pursuant to the ESA, the use of military expended materials - munitions during testing activities as described under Alternative 1 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.6.1.2 Impacts from Military Expended Materials – Munitions Under Alternative 2

Impacts from Military Expended Materials – Munitions Under Alternative 2 for Training Activities

Because activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, ingestion stress experienced by fishes from military expended materials and munitions under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with training activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of military expended materials - munitions during training activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

Impacts from Military Expended Materials – Munitions Under Alternative 2 for Testing Activities

Because activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, ingestion stress experienced by fishes from military expended materials and munitions under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of military expended materials - munitions during testing activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

3.6.3.6.1.3 Impacts from Military Expended Materials – Munitions Under the No Action Alternative

Impacts from Military Expended Materials – Munitions Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Ingestion stressors for fishes from military expended materials such as munitions would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.6.2 Impacts from Military Expended Materials – Other than Munitions

Fishes feed throughout the water column and could mistake many types of marine debris for prey items. Ingesting nonfood items is common among a variety of marine fishes, particularly those that feed on the seafloor (Boerger et al., 2010; Hoss & Settle, 1990; Jackson et al., 2000). Many fishes are also known to accidentally ingest plastic materials, and the extent to which an individual fish might discriminate between a plastic item perceived as prey and an indistinct or less appealing shape is not clear. Once eaten, any type of plastic could cause digestive problems for the fish (Danner et al., 2009). Fishes have been reported to ingest a variety of materials or debris, such as plastic pellets, bags, rope, and line (Hoss & Settle, 1990; Jackson et al., 2000). As discussed above in Section 3.6.3.6 (Ingestion Stressors), some fish species such as the ocean sunfish eat jellyfish and may consume a decelerator/parachute at or just below the surface in the open ocean by accident. Larger filter feeders such as whale sharks, basking sharks, and manta rays could also inadvertently ingest a small or medium decelerator/parachute.

Chaff is used throughout the Study Area. It is composed of an aluminum alloy coating on glass fibers of silicon dioxide and is released or dispensed in cartridges or projectiles that contain millions of fibers. Based on the small size of chaff fibers, fish would likely not confuse the fibers with prey items or purposefully feed on them. However, some fishes could occasionally ingest low concentrations of chaff incidentally while feeding on prey items on the surface, in the water column, or the seafloor. Chaff fiber ingestion is not expected to impact fishes based on the low concentration that could reasonably be ingested and the small size of the chaff fibers. Therefore, exposure to chaff would cause no injury, mortality, or tissue damage to fishes. Potential impacts of chaff ingestion by fish are not discussed further. Impacts of ingestion of the end caps or pistons associated with chaff cartridges are analyzed together with impacts of flares below.

Chaff end caps and pistons sink in saltwater (U.S. Department of the Navy, 1999). Fishes feeding on the where chaff canisters and flares are expended (e.g., range complexes would be more likely to encounter and ingest these items than in other locations. Ingested end caps or pistons could disrupt a fish's feeding behavior or digestive processes. If the item is particularly large relative to the fish ingesting it, the item could become permanently encapsulated by the stomach lining, and potentially lead to starvation and death (Danner et al., 2009; Hoss & Settle, 1990). The highest density of chaff and flare end caps/pistons would be expended in the Southern California Range Complex. Based on the low environmental concentration (Section 3.5, Habitats), it is unlikely that a larger number of fishes would ingest an end cap or piston, much less a harmful quantity. Furthermore, a fish might expel the item before swallowing it. The number of fish potentially impacted by ingestion of end caps or pistons would be low based on the low environmental concentration and population-level impacts are not expected to occur.

As described above, surface-feeding fishes have little opportunity to ingest end caps or pistons before they sink. However, some of these items could become entangled in dense algal mats near the surface. Predatory open-ocean fishes, such as tunas, dolphinfishes, and billfishes, are attracted to the many small prey species associated with algal mats. While foraging near the floating mats, predatory fishes may incidentally ingest end caps and pistons. The density of these items in any given location would vary based on release points and dispersion by wind and water currents. The number of end-caps and pistons that would remain at or just below the surface in algal mats and potentially available to fish is unknown. Unlike other plastic types of marine debris, end caps and pistons are heavier than water and not expected to float unless they are enmeshed in algal or other floating debris.

Most materials associated with airborne mine neutralization system activities are recovered, but pieces of fiber optic cable may be expended (U.S. Department of the Navy, 2001a). For a discussion of the physical characteristics of these expended materials, where they are used, and the number of activities in each alternative, please see Section 3.0.3.3.5.1 (Wires and Cables). Only small amounts of fiber optic cable would be deposited onto the seafloor each year, and the small amount of fiber optic cable expended during training and testing would sink to the seafloor. Highly migratory pelagic predators (e.g., tunas, billfishes, pelagic sharks) would be unlikely to encounter the small, dispersed lengths of fiber optic cable unless they were in the immediate area when the cable was expended. The low number of fiber optic cables expended in the Study Area during this activity makes it unlikely that fishes would encounter any fiber optic cables. Potential impacts of fiber optic cable ingestion by fishes are not discussed further.

As stated in Section 3.0.3.3.5.3 (Biodegradable Polymer), based on the constituents of the biodegradable polymer, it is anticipated that the material will breakdown into small pieces within a few days to weeks. These small pieces will breakdown further and dissolve into the water column within weeks to a few months and could potentially be incidentally ingested by fishes. Because the final products of the breakdown are all environmentally benign, the Navy does not expect the use of biodegradable polymer to have any negative impacts for fishes.

3.6.3.6.2.1 Impacts from Military Expended Materials – Other than Munitions Under Alternative 1

Impacts from Military Expended Materials – Other than Munitions Under Alternative 1 for Training Activities

As indicated in Section 3.0.3.3.6.3 (Military Expended Materials Other Than Munitions) under Alternative 1, activities involving target materials use would occur throughout the Study Area. Some of the ESA-listed species occur where target materials could potentially be expended.

As indicated in Section 3.0.3.3.6.3 (Military Expended Materials Other Than Munitions) under Alternative 1, activities that expend chaff and flares occur in the open ocean areas of the Hawaii and Southern California Range Complexes. No potential impacts would occur from the chaff itself, but there is some potential for fishes to ingest the end caps or pistons associated with the chaff cartridges. The potential exists for large, open-ocean predators (e.g., tunas, billfishes, pelagic sharks) to ingest self-protection flare end caps or pistons as they float on the water column for some time. In a 2013 study, plastic and other anthropogenic debris was found in seven large pelagic predatory fishes from the Hawaiian Island Archipelago region (Choy & Drazen, 2013). Pieces of plastic, different types of fishing and nautical lines, and rope were most commonly found materials in their stomachs (Choy & Drazen, 2013). In addition, Boerger et al. (2010) found that 35 percent of the fishes captured in Manta (surface) trawls in the North Pacific Gyre had ingested plastic. End caps and pistons sink in saltwater (U.S. Department of the Navy, 1999), which reduces the likelihood of ingestion by surface-feeding fishes. However, some of the material could remain at or near the surface, and predatory fishes may incidentally ingest these items. The highest density of chaff and flare end caps/pistons would be expended in the Southern California Range Complex.

Based on the low density of expended endcaps and pistons, the encounter rate would be extremely low, and the ingestion rate even lower. The number of fishes potentially impacted by ingestion of end caps or pistons would be minimal based on the low environmental concentration. Population-level effects would not be expected. While these activities could overlap with steelhead, gulf grouper, giant manta ray, oceanic whitetip shark, and scalloped hammerhead sharks, the likelihood of ingestion would be extremely low given the low abundance of these species in the Study Area and the dispersed nature of the activity. In addition, offshore species such as giant manta rays or oceanic whitetip sharks could mistake larger military expended materials other than munitions for prey during testing activities, even though these species typically forage at or near the surface. It is likely that these species would "taste" and then spit it out if an item were accidentally ingested; if ingested, the item would most likely pass through the digestive tract without causing harm. The majority of the physical and biological features required by steelhead are applicable to freshwater and estuaries (i.e., spawning sites, rearing sites, and migration corridors), and are outside the Study Area. Therefore, munitions use would not affect steelhead critical habitat.

Although ingestion of military expended materials identified here could result in sublethal or lethal effects, the likelihood of ingestion is low based on the dispersed nature of the materials, the limited encounter rate of fishes to the expended items, behavioral mechanisms for expelling the item, and the capacity of the fish's digestive system to simply pass the item through as waste. Based on these factors, the number of fishes potentially impacted by ingestion of military expended materials (such as chaff and flare end caps and pistons) would be low, and no population-level effects would be expected.

Pursuant to the ESA, the use of military expended materials other than munitions during training activities as described under Alternative 1 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

Impacts from Military Expended Materials – Other than Munitions Under Alternative 1 for Testing Activities

As indicated in Section 3.0.3.3.6.3 (Military Expended Materials Other Than Munitions) under Alternative 1, testing activities involving target materials use would occur throughout the Study Area. Some of the ESA-listed species, such as scalloped hammerhead sharks, occur where target materials could potentially be expended.

As indicated in Section 3.0.3.3.6.3 (Military Expended Materials Other Than Munitions) under Alternative 1, testing activities that expend chaff and flares occur in the open ocean areas of the Hawaii and Southern California Range Complexes. No potential impacts would occur from the chaff itself, but there is some potential for fishes, including ESA-listed species to ingest the end caps or pistons associated with the chaff cartridges. The number and location of testing activities under Alternative 1 would be higher for chaff and lower for flares compared to training activities. Even though there are differences in the quantity of military expended material other than munitions during testing activities, the impacts would be similar as those described above for training activities.

Military expended materials other than munitions would have the potential for effect on steelhead, gulf grouper, and scalloped hammerhead sharks in the Study Area, however for reasons presented in the training discussion, likelihood of ingestion of these expended materials and potential to impact fishes, including ESA-listed species, would be low. As described above for training activities, offshore species such as giant manta rays or oceanic whitetip sharks could mistake larger military expended materials other than munitions for prey and then spit it out if an item were accidentally ingested. For the same reasons as stated under the training activities discussion, military expended materials other than munitions would not affect steelhead critical habitat.

Pursuant to the ESA, the use of military expended materials other than munitions during testing activities as described under Alternative 1 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.6.2.2 Impacts from Military Expended Materials – Other than Munitions Under Alternative 2

Impacts from Military Expended Materials – Other than Munitions Under Alternative 2 for Training Activities

Because training activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, ingestion stress experienced by fishes from military expended materials other than munitions under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with training activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of military expended materials other than munitions during training activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

Impacts from Military Expended Materials – Other than Munitions Under Alternative 2 for Testing Activities

Because testing activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, ingestion stress experienced by fishes from military expended materials other than munitions under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of military expended materials other than munitions during testing activities as described under Alternative 2 would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks.

3.6.3.6.2.3 Impacts from Military Expended Materials – Other than Munitions Under the No Action Alternative

Impacts from Military Expended Materials – Other than Munitions Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. Ingestion stressors for fishes from military expended materials other than munitions would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.7 Secondary Stressors

This section analyzes potential impacts on fishes exposed to stressors indirectly through impacts on prey availability and habitat (e.g., sediment or water quality, and physical disturbance). For the purposes of this analysis, indirect impacts on fishes via sediment or water that do not require trophic transfer (e.g., bioaccumulation) in order to be observed are considered here. It is important to note that the terms “indirect” and “secondary” do not imply reduced severity of environmental consequences, but instead describe how the impact may occur in an organism or its ecosystem.

Stressors from Navy training and testing activities could pose secondary or indirect impacts on fishes via habitat (e.g., sediment, and water quality) and prey availability. These include (1) explosives and explosion byproducts; (2) metals; (3) chemicals; and (4) other materials such as targets, chaff, and plastics. Activities associated with these stressors are detailed in Tables 2.6-1 to 2.6-5, and analyses of their potential impacts are discussed in Section 3.2 (Sediments and Water Quality), Section 3.4 (Invertebrates), and Section 3.5 (Habitats). The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs and precious coral beds) to avoid potential impacts from explosives and physical disturbance and strike stressors on seafloor resources in mitigation areas throughout the Study Area (Section 5.4.1, Mitigation Areas for Seafloor Resources). This mitigation will consequently help avoid potential impacts on fishes that shelter in and feed on shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks.

Explosions

Secondary impacts on fishes resulting from explosions at the surface, in the water column, or on the bottom would be associated with changes to habitat structure and effects to prey species. Most explosions on the bottom would occur in soft bottom habitat and would displace some amount of sediment, potentially resulting in cratering. However, water movement would redistribute the affected sediment over time. A small amount of sediment would be suspended in the water column temporarily (turbidity), but would resettle to the bottom. Activities that inadvertently result in explosions on or near hard bottom habitat or reefs could break hard structures and reduce the amount of colonizing surface available to encrusting organisms (e.g., corals, sponges). Given the large spatial area of the range complexes compared to the small percentage covered by hard bottom habitat, it is unlikely that most of the small, medium, and large projectiles expended in the Study Area would fall onto this habitat type. Furthermore, these activities are distributed within discrete locations within the Study Area, and the overall footprint of these areas is quite small with respect to the spatial extent of biogenic habitat within the Study Area.

Sinking exercises could also provide secondary impacts on deep sea populations. These activities occur in open-ocean areas, outside of the coastal range complexes, with potential direct disturbance or strike impacts on deep-sea fishes, as covered in Section 3.6.3.4 (Physical Disturbance and Strike Stressors). Secondary impacts on these fishes could occur after the ship hulks sink to the seafloor. Over time, the ship hulk would be colonized by marine organisms that attach to hard surfaces. For fishes that feed on these types of organisms, or whose abundances are limited by available hard structural habitat, the ships that are sunk during sinking exercises could provide an incidental beneficial impact on the fish community (Love & York, 2005; Macreadie et al., 2011).

The alternatives could result in localized and temporary changes to the benthic community during activities that impact fish habitat. Fish habitat could become degraded during activities that would strike the seafloor or introduce military expended materials, bombs, projectiles, missiles, rockets or fragments to the seafloor. During or following activities that impact benthic habitats, fish species may experience loss of available benthic prey at locations in the Study Area where these items might be expended. Additionally, plankton and zooplankton that are eaten by fishes may also be negatively impacted by these same expended materials. The spatial area of habitat impacted by the Proposed Action would be relatively small compared to the available habitat in the Study Area. However, there would still be vast expanses of habitat adjacent to the areas of habitat impact that would remain undisturbed by the Proposed Action. The majority of the physical and biological features required by steelhead are applicable to freshwater and estuaries (i.e., spawning sites, rearing sites, and migration corridors), and are outside the Study Area. Therefore, there would be no impacts associated with secondary stressors.

Explosion By-Products

Deposition of undetonated explosive materials into the marine environment can be reasonably well estimated by the known failure and low-order detonation rates of high explosives. Undetonated explosives associated with mine neutralization activities are collected after the activity is complete; therefore, potential impacts are assumed to be inconsequential for these training and testing activities, but other activities could result in unexploded munitions and unconsumed explosives on the seafloor. Fishes may be exposed by contact with the explosive, contact with contaminants in the sediment or water, and ingestion of contaminated sediments.

High-order explosions consume most of the explosive material, creating typical combustion products. In the case of royal demolition explosive, 98 percent of the products are common seawater constituents and the remainder is rapidly diluted below threshold impact level. Explosion byproducts associated with high order detonations present no indirect stressors to fishes through sediment or water. However, low order detonations and unexploded munitions present elevated likelihood of impacts on fishes.

Indirect impacts of explosives and unexploded munitions to fishes via sediment is possible in the immediate vicinity of the munitions. Degradation of explosives proceeds via several pathways discussed in Section 3.2 (Sediments and Water Quality). Degradation products of royal demolition explosive are not toxic to marine organisms at realistic exposure levels (Rosen & Lotufo, 2010). Trinitrotoluene (TNT) and its degradation products impact developmental processes in fishes and are acutely toxic to adults at concentrations similar to real-world exposures (Halpern et al., 2008b; Rosen & Lotufo, 2010). Relatively low solubility of most explosives and their degradation products means that concentrations of these contaminants in the marine environment are relatively low and readily diluted. Furthermore, while explosives and their degradation products were detectable in marine sediment approximately 0.15–0.3 m away from degrading munitions, the concentrations of these compounds were not statistically distinguishable from background beyond 1–2 m from the degrading munitions (Section 3.2, Sediments and Water Quality). Taken together, it is likely that various life stages of fishes could be impacted by the indirect impacts of degrading explosives within a very small radius of the explosive (0.3–2 m).

If a high-explosive munitions does not explode, it would sink to the bottom. In the unlikely event that explosive material, high-melting-point explosive (known as HMX), or royal demolition explosive (known as RDX) is exposed on the ocean floor, it would break down in a few hours (U.S. Department of the Navy, 2001a). High-melting-point explosive or royal demolition explosive would not accumulate in the tissues of fishes (Lotufo et al., 2010; Price et al., 1998). Fish may take up trinitrotoluene (TNT) from the water when it is present at high concentrations but not from sediments (Lotufo et al., 2010). The rapid dispersal and dilution of trinitrotoluene (TNT) expected in the marine water column reduces the likelihood of a fish encountering high concentrations of trinitrotoluene (TNT) to near zero.

A series of research efforts focused on World War II underwater munitions disposal sites in Hawaii (Briggs et al., 2016; Edwards et al., 2016; Kelley et al., 2016; Koide et al., 2016; University of Hawaii, 2010) and an intensively used live fire range in the Mariana Islands (Smith & Marx, 2016) provide information in regard to the impacts of undetonated materials and unexploded munitions on marine life. A summary of this literature which investigated water and sediment quality impacts, on a localized scale, from munitions ocean disposal sites and ocean disposed dredge spoils sites is presented in the Sediment and Water Quality section and specifically in Section 3.2.3.1 (Explosives and Explosives Byproducts) and Section 3.2.3.3 (Metals). Findings from these studies indicate that there were no adverse impacts on the local ecology from the presence of degrading munitions and there was no bioaccumulation of munitions-related chemicals in local marine species. Therefore, water quality effects from the use of munitions, expended material, or devices would be negligible, would have no long-term effect on water quality, and therefore would not constitute a secondary indirect stressor for fishes.

Metals

Certain metals and metal-containing compounds at concentrations above background levels (e.g., cadmium, chromium, lead, mercury, zinc, copper, manganese, and many others) can be toxic to fishes (Wang & Rainbow, 2008). Metals are introduced into seawater and sediments as a result of training and testing activities involving vessel hulks, targets, munitions, batteries, and other military expended materials (Section 3.2, Sediments and Water Quality). Some metals bioaccumulate, and physiological impacts begin to occur only after several trophic transfers concentrate the toxic metals (U.S. Department of the Navy, 2012). Indirect effects of metals on fish via sediment and water involve concentrations several orders of magnitude lower than concentrations achieved via bioaccumulation. Fishes may be exposed by contact with the metal, contact with contaminants in the sediment or water, and ingestion of contaminated sediments. Concentrations of metals in seawater are orders of magnitude lower than concentrations in marine sediments. It is extremely unlikely that fishes would be indirectly impacted by toxic metals via the water.

Chemicals

Several Navy training and testing activities introduce potentially harmful chemicals into the marine environment, principally flares and propellants for rockets, missiles, and torpedoes. Polychlorinated biphenyls are discussed in Section 3.2 (Sediments and Water Quality), but there is no additional risk to fish because the Proposed Action does not introduce this chemical into the Study Area and the use of polychlorinated biphenyls has been nearly zero since 1979. Properly functioning flares, missiles, rockets, and torpedoes combust most of their propellants, leaving benign or readily diluted soluble combustion byproducts (e.g., hydrogen cyanide). Operational failures allow propellants and their degradation products to be released into the marine environment.

The greatest risk to fishes from flares, missiles, and rocket propellants is perchlorate, which is highly soluble in water, persistent, and impacts metabolic processes in many plants and animals. Fishes may be exposed by contact with contaminated water or ingestion of re-suspended contaminated sediments. Since perchlorate is highly soluble, it does not readily adsorb to sediments. Therefore, missile and rocket fuels pose no risk of indirect impact on fishes via sediment. In contrast, the principal toxic components of torpedo fuel, propylene glycol dinitrate and nitrodiphenylamine, adsorbs to sediments, have relatively low toxicity, and are readily degraded by biological processes (Section 3.2, Sediments and Water Quality). It is conceivable that various life stages of fishes could be indirectly impacted by propellants via sediment in the immediate vicinity of the object (e.g., within a few inches), but these potential impacts would diminish rapidly as the propellant degrades.

Other Materials

Some military expended materials (e.g., decelerators/parachutes) could become remobilized after their initial contact with the seafloor (e.g., by waves or currents) and could pose an entanglement or ingestion hazard for fishes. For example, in some bottom types without strong currents, hard-packed sediments, and low biological productivity, items such as projectiles might remain intact for some time before becoming degraded or broken down by natural processes. These potential impacts may cease only (1) when the military expended materials are too massive to be mobilized by typical oceanographic processes, (2) if the military expended materials become encrusted by natural processes and incorporated into the seafloor, or (3) when the military expended materials become permanently buried. In this scenario, a decelerator/parachute could initially sink to the seafloor, but then be transported laterally through the water column or along the seafloor, increasing the opportunity for entanglement. In the unlikely event that a fish would become entangled, injury or mortality could result. In contrast to large decelerators/parachutes, other devices with decelerators such as sonobuoys are typically used in deep open ocean areas. These areas are much lower in fish numbers and diversity, so entanglement hazards are greatly reduced for commercially and recreationally targeted species (ex. tuna, swordfish, etc.), as well as mesopelagic prey of other species. The entanglement stressor would eventually cease to pose an entanglement risk as it becomes encrusted or buried.

3.6.3.7.1 Impacts on Habitat

The Proposed Action could result in localized and temporary changes to the benthic community (see Section 3.5, Habitats) during activities that impact fish habitat. Hard bottom is important habitat for many different species of fish, including those fishes managed by various fishery management plans. Fish habitat could become degraded during activities that would strike the seafloor or introduce military expended materials, bombs, projectiles, missiles, rockets, or fragments to the seafloor. The spatial area of habitat impacted by the Proposed Action would be relatively small compared to the available habitat in the Study Area. However, there would still be vast expanses of habitat adjacent to the areas of habitat impact that would remain undisturbed by the Proposed Action.

Pursuant to the ESA, secondary stressors such as impacts on habitat from testing and training activities, as described above, would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.3.7.2 Impacts on Prey Availability

Impacts on fish prey availability resulting from explosives, explosives byproducts, unexploded munitions, metals, and chemicals would differ depending upon the type of prey species in the area, but would likely be negligible overall and have no population-level impacts on fishes. As discussed in Section 3.6.3.1 (Acoustic Stressors), fishes with swim bladders are more susceptible to blast injuries than fishes without swim bladders. During or following activities that impact benthic habitats, fish species may experience loss of available benthic prey at locations in the Study Area where these items might be expended. Additionally, plankton and zooplankton that are eaten by fishes may also be negatively impacted by these same expended materials some species of zooplankton that occur in the Pacific such as Pacific oyster (*Crassostrea gigas*) larvae have been found feeding on microplastics (Cole & Galloway, 2015).

In addition to physical effects of an underwater blast such as being stunned, prey might have behavioral reactions to underwater sound. For instance, prey species might exhibit a strong startle reaction to detonations that might include swimming to the surface or scattering away from the source. This startle and flight response is the most common secondary defense among animals (Hanlon and Messenger, 1996). The sound from underwater explosions might induce startle reactions and temporary dispersal of schooling fishes if they are within close proximity (Popper et al., 2014; Wright, 1982).

The abundances of fish and invertebrate prey species near the detonation point could be diminished for a short period of time before being repopulated by animals from adjacent waters. The sound from underwater explosions might induce startle reactions and temporary dispersal of schooling fishes, potentially increasing visibility to predators, if they are within close proximity (Kastelein et al., 2008). Alternatively, any prey species that would be directly injured or killed by the blast could draw in scavengers from the surrounding waters that would feed on those organisms, and in turn could be susceptible to becoming directly injured or killed by subsequent explosions. Any of these scenarios would be temporary, only occurring during activities involving explosives, and no lasting impact on prey availability or the food web would be expected. Indirect impacts of underwater detonations and high explosive munitions use under the Proposed Action would not result in a decrease in the quantity or quality of fish populations in the Study Area.

Pursuant to the ESA, secondary stressors such as impacts on prey availability from testing and training activities, as described above, would have no effect on steelhead critical habitat and no effect on gulf grouper, but may affect the ESA-listed Eastern Pacific Distinct Population Segment of scalloped hammerhead shark, steelhead, giant manta rays, and oceanic whitetip sharks. The Navy consulted with NMFS, as required by section 7(a)(2) of the ESA.

3.6.4 Summary of Potential Impacts on Fishes

3.6.4.1 Combined Impacts of All Stressors Under Alternative 1

As described in Section 3.0.3.5 (Resource-Specific Impacts Analysis for Multiple Stressors), this section evaluates the potential for combined impacts of all the stressors from the Proposed Action. The analysis and conclusions for the potential impacts from each individual stressor are discussed in the analyses of each stressor in the sections above and summarized in Section 3.6.5 (Endangered Species Act Determinations).

Additive Stressors – There are generally two ways that a fish could be exposed to multiple stressors. The first would be if a fish were exposed to multiple sources of stress from a single event or activity (e.g., a mine warfare activity may include the use of a sound source and a vessel). The potential for a combination of these impacts from a single activity would depend on the range of effects of each stressor and the response or lack of response to that stressor. Most of the activities as described in the Proposed Action involve multiple stressors; therefore, it is likely that if a fish were within the potential impact range of those activities, it may be impacted by multiple stressors simultaneously. This would be even more likely to occur during large-scale exercises or activities that span a period of days or weeks (such as a sinking exercises or composite training unit exercise).

Secondly, a fish could also be exposed to a combination of stressors from multiple activities over the course of its life. This is most likely to occur in areas where training and testing activities are more concentrated (e.g., near naval ports, testing ranges, and routine activity locations) and in areas that individual fish frequent because it is within the animal's home range, migratory corridor, spawning or feeding area. Except for in the few concentration areas mentioned above, combinations are unlikely to occur because training and testing activities are generally separated in space and time in such a way that it would be very unlikely that any individual fish would be exposed to stressors from multiple activities. However, animals with a home range intersecting an area of concentrated Navy activity have elevated exposure risks relative to animals that simply transit the area through a migratory corridor. The majority of the proposed training and testing activities occur over a small spatial scale relative to the entire Study Area, have few participants, and are of a short duration (on the order of a few hours or less).

Synergistic Stressors – Multiple stressors may also have synergistic effects. For example, fishes that experience temporary hearing loss or injury from acoustic stressors could be more susceptible to physical strike and disturbance stressors via a decreased ability to detect and avoid threats. Fishes that experience behavioral and physiological consequences of ingestion stressors could be more susceptible to entanglement and physical strike stressors via malnourishment and disorientation. These interactions are speculative, and without data on the combination of multiple Navy stressors, the synergistic impacts from the combination of Navy stressors are difficult to predict in any meaningful way. Navy research and monitoring efforts include data collection through conducting long-term studies in areas of Navy activity, occurrence surveys over large geographic areas, biopsy of animals occurring in areas of Navy activity, and tagging studies where animals are exposed to Navy stressors. These efforts are intended to contribute to the overall understanding of what impacts may be occurring overall to animals in these areas.

The combined impacts under Alternative 1 of all stressors would not be expected to impact fish populations because (1) activities involving more than one stressor are generally short in duration, and (2) such activities are dispersed throughout the Study Area. Existing conditions would not change considerably under Alternative 1; therefore, no detectable impacts on fish populations would occur with implementation of Alternative 1.

3.6.4.2 Combined Impacts of All Stressors Under Alternative 2

The combined impacts under Alternative 2 of all stressors would not be expected to impact fish populations because (1) activities involving more than one stressor are generally short in duration, and (2) such activities are dispersed throughout the Study Area. Existing conditions would not change considerably under Alternative 2; therefore, no detectable impacts on fish populations would occur after the implementation of Alternative 2.

3.6.4.3 Combined Impacts of All Stressors Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the HSTT Study Area. The combined impacts of all stressors for fishes would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities, and no impacts on fish population would occur.

3.6.5 Endangered Species Act Determinations

Pursuant to the ESA, the Navy has consulted with NMFS on Alternative 1 (the Preferred Alternative) as required by section 7(a)(2) of the ESA and determined that training and testing activities may affect the giant manta ray, oceanic whitetip shark, Eastern Pacific DPS scalloped hammerhead shark, and Southern California DPS steelhead. The Navy has also determined that training and testing activities would have no effect on designated critical habitat for steelhead because the Proposed Action does not have any elements with the potential to modify such habitat.

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REFERENCES

Abadía-Cardoso, A., D. E. Pearse, S. Jacoson, J. Marshall, D. Dalrymple, F. Kawasaki, G. Ruiz-Campos, and J. C. Garza. (2016). Population genetic structure and ancestry of steelhead/rainbow trout (*Oncorhynchus mykiss*) at the extreme southern edge of their range in North America. *Conservation Genetics, 17*, 675–689.

Able, K. W., and M. P. Fahay. (1998). *The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight*. New Brunswick, NJ: Rutgers University Press.

Allen, M. J. (2006). Pollution. In L. G. Allen, D. J. Pondella, II, & M. H. Horn (Eds.), *The Ecology of Marine Fishes: California and Adjacent Waters* (pp. 595–610). Berkeley, CA: University of California Press.

Anderson, D. M., P. M. Glibert, and J. M. Burkholder. (2002). Harmful algal blooms and eutrophication: Nutrient sources, composition, and consequences. *Estuaries, 25*(4, Part B), 704–726.

Arfsten, D. P., C. L. Wilson, and B. J. Spargo. (2002). Radio frequency chaff: The effects of its use in training on the environment. *Ecotoxicology and Environmental Safety, 53*, 1–11.

Armstrong, J. D., D.-C. Hunter, R. J. Fryer, P. Rycroft, and J. E. Orpwood. (2015). Behavioural responses of Atlantic salmon to mains frequency magnetic fields. *Scottish Marine and Freshwater Science, 6*, 1–17.

Asch, R. G. (2015). Climate change and decadal shifts in the phenology of larval fishes in the California Current ecosystem. *PNAS*, 4065–4074.

Astrup, J. (1999). Ultrasound detection in fish—a parallel to the sonar-mediated detection of bats by ultrasound-sensitive insects? *Comparative Biochemistry and Physiology, Part A, 124*, 19–27.

Baum, E. (1997). *Maine Atlantic Salmon: A National Treasure*. Hermon, ME: Atlantic Salmon Unlimited.

Baum, J., E. Medina, J. A. Musick, and M. Smale. (2015). *Carcharhinus longimanus. The International Union for Conservation of Nature Red List of Threatened Species 2015: e.T39374A85699641*. Retrieved from http://www.iucnredlist.org/details/39374/0.

Baum, J. K., R. A. Myers, D. G. Kehler, B. Worm, S. J. Harley, and P. A. Doherty. (2003). Collapse and conservation of shark populations in the northwest Atlantic. *Science, 299*(5605), 389–392.

Bergstad, O. A., T. Falkenhaug, O. S. Astthorsson, I. Byrkjedal, A. V. Gebruk, U. Piatkowski, I. G. Priede, R. S. Santos, M. Vecchione, P. Lorance, and J. D. M. Gordon. (2008). Towards improved understanding of the diversity and abundance patterns of the mid-ocean ridge macro- and megafauna. *Deep-Sea Research II, 55*(1–2), 1–5.

Bermudez, J. R., U. Riebesell, A. Larsen, and M. Winder. (2016). Ocean acidification reduces transfer of essential biomolecules in a natural plankton community. *Scientific Reports, 6*, 1–8.

Bester, C. (1999). *Biological profiles: Scalloped hammerhead*. Retrieved from https://www.floridamuseum.ufl.edu/fish/discover/species-profiles/sphyrna-lewini/.

Bignami, S., S. Sponaugle, and R. K. Cowen. (2013). Response to ocean acidification in larvae of a large tropical marine fish, *Rachycentron canadum*. *Global Change Biology, 19*(4), 996–1006.

Bleckmann, H., and R. Zelick. (2009). Lateral line system of fish. *Integrative Zoology, 4*(1), 13–25.

Boehlert, G. W., and A. B. Gill. (2010). Environmental and ecological effects of ocean renewable energy development: A current synthesis. *Oceanography, 23*(2), 68–81.

Boerger, C. M., G. L. Lattin, S. L. Moore, and C. J. Moore. (2010). Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. *Marine Pollution Bulletin, 60*(12), 2275–2278.

Booman, C., H. Dalen, H. Heivestad, A. Levesen, T. van der Meeren, and K. Toklum. (1996). (Seismic-fish) Effekter av luftkanonskyting pa egg, larver og ynell. *Havforskningsinstituttet*.

Botsford, L. W., D. R. Brumbaugh, C. Grimes, J. B. Kellner, J. Largier, M. R. O'Farrell, S. Ralston, E. Soulanille, and V. Wespestad. (2009). Connectivity, sustainability, and yield: Bridging the gap between conventional fisheries management and marine protected areas. *Reviews in Fish Biology and Fisheries, 19*(1), 69–95.

Bracciali, C., D. Campobello, C. Giacoma, and G. Sara. (2012). Effects of nautical traffic and noise on foraging patterns of Mediterranean damselfish (*Chromis chromis*). *PLoS ONE, 7*(7), e40582.

Brander, K. (2010). Impacts of climate change on fisheries. *Journal of Marine Systems, 79*(3–4), 389–402.

Brander, K. M. (2007). Global fish production and climate change. *Proceedings of the National Academy of Sciences of the United States of America, 104*(50), 19709–19714.

Braun, C. D., G. B. Skomal, S. R. Thorrold, and M. L. Berumen. (2015). Movements of the reef manta ray (*Manta alfredi*) in the Red Sea using satellite and acoustic telemetry. *Marine Biology, 162*, 2351–2362.

Brehmer, P., F. Gerlotto, C. Laurent, P. Cotel, A. Achury, and B. Samb. (2007). Schooling behaviour of small pelagic fish: phenotypic expression of independent stimuli. *Marine Ecology Progress Series, 334*, 263–272.

Briggs, C., S. M. Shjegstad, J. A. K. Silva, and M. H. Edwards. (2016). Distribution of chemical warfare agent, energetics, and metals in sediments at a deep-water discarded military munitions site. *Deep Sea Research Part II: Topical Studies in Oceanography, 128*, 63–69.

Bruintjes, R., J. Purser, K. A. Everley, S. Mangan, S. D. Simpson, and A. N. Radford. (2016). Rapid recovery following short–term acoustic disturbance in two fish species. *Royal Society - Open Science, 3*(1), 150686.

Buerkle, U. (1968). Relation of pure tone thresholds to background noise level in the Atlantic cod (*Gadus morhua*). *Journal of the Fisheries Research Board of Canada, 25*, 1155–1160.

Buerkle, U. (1969). Auditory masking and the critical band in Atlantic cod (*Gadus morhua*). *Journal of the Fisheries Research Board of Canada, 26*, 1113–1119.

Bullock, T. H., D. A. Bodznick, and R. G. Northcutt. (1983). The phylogenetic distribution of electroreception—evidence for convergent evolution of a primitive vertebrate sense modality. *Brain Research Reviews, 6*(1), 25–46.

Buran, B. N., X. Deng, and A. N. Popper. (2005). Structural variation in the inner ears of four deep-sea elopomorph fishes. *Journal of Morphology, 265*, 215–225.

Bureau of Ocean Energy Management. (2011). *Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species*. Camarillo, CA: U.S. Department of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region.

California Coastal Commission. (2018). *The Problem with Marine Debris*. Retrieved from https://www.coastal.ca.gov/publiced/marinedebris.html.

California Department of Transportation. (2001). *Pile Installation Demonstration Project Marine Mammal Impact Assessment* (San Francisco - Oakland Bay Bridge East Span Seismic Safety Project). San Francisco, CA: Strategic Environmental, Inc. and Illingworth & Rodkin, Inc.

Cao, L., S. Wang, M. Zheng, and H. Zhang. (2014). Sensitivity of ocean acidification and oxygen to the uncertainty in climate change. *Environmental Research Letters, 9*(2014), 1–10.

Carlson, T., M. Hastings, and A. N. Popper. (2007). *Memorandum: Update on Recommendations for Revised Interim Sound Exposure Criteria for Fish during Pile Driving Activities* (Arlington Memo Update 12-21-07). Sacramento, CA: California Department of Transportation.

Casper, B., P. Lobel, and H. Yan. (2003). The hearing sensitivity of the little skate, *Raja erinacea*: A comparison of two methods. *Environmental Biology of Fishes, 68*, 371–379.

Casper, B., and D. Mann. (2006). Evoked potential audiograms of the nurse shark (*Ginglymostoma cirratum*) and the yellow stingray (*Urabatis jamaicensis*). *Environmental Biology of Fishes, 76*(1), 101–108.

Casper, B. M., and D. A. Mann. (2009). Field hearing measurements of the Atlantic sharpnose shark, *Rhizoprionodon terraenovae*. *Journal of Fish Biology, 75*(10), 2768–2776.

Casper, B. M., M. B. Halvorsen, and A. N. Popper. (2012a). Are Sharks Even Bothered by a Noisy Environment? In A. N. Popper & A. D. Hawkins (Eds.), *The Effects of Noise on Aquatic Life II* (Vol. 730). New York, NY: Springer.

Casper, B. M., A. N. Popper, F. Matthews, T. J. Carlson, and M. B. Halvorsen. (2012b). Recovery of barotrauma injuries in Chinook salmon, *Oncorhynchus tshawytscha* from exposure to pile driving sound. *PLoS ONE, 7*(6), e39593.

Casper, B. M., M. B. Halvorsen, F. Matthews, T. J. Carlson, and A. N. Popper. (2013a). Recovery of barotrauma injuries resulting from exposure to pile driving sound in two sizes of hybrid striped bass. *PLoS ONE, 8*(9), e73844.

Casper, B. M., M. E. Smith, M. B. Halvorsen, H. Sun, T. J. Carlson, and A. N. Popper. (2013b). Effects of exposure to pile driving sounds on fish inner ear tissues. *Comparative Biochemistry and Physiology, Part A, 166*(2), 352–360.

Casper, B. M., M. B. Halvorsen, T. J. Carlson, and A. N. Popper. (2017). Onset of barotrauma injuries related to number of pile driving strike exposures in hybrid striped bass. *The Journal of the Acoustical Society of America, 141*(6), 4380.

Castro, J. I. (1983). *The Sharks of North American Waters*. College Station, TX: Texas A&M University Press.

Catano, L. B., B. K. Gunn, M. C. Kelley, and D. E. Burkepile. (2015). Predation risk, resource quality, and reef structural complexity shape territoriality in a coral reef herbivore. *PLoS ONE, 10*(2), e0118764.

Chapman, C. J., and A. D. Hawkins. (1973). Field study of hearing in cod, *Gadus morhua* L. *Journal of Comparative Physiology, 85*(2), 147–167.

Cheung, W. W. L., R. Watson, T. Morato, T. J. Pitcher, and D. Pauly. (2007). Intrinsic vulnerability in the global fish catch. *Marine Ecology-Progress Series, 333*, 1–12.

Choy, C. A., and J. C. Drazen. (2013). Plastic for dinner? Observations of frequent debris ingestion by pelagic predatory fishes from the central North Pacific. *Marine Ecology Progress Series, 485*, 155–163.

Codarin, A., L. E. Wysocki, F. Ladich, and M. Picciulin. (2009). Effects of ambient and boat noise on hearing and communication in three fish species living in a marine protected area (Miramare, Italy). *Marine Pollution Bulletin, 58*(12), 1880–1887.

Cole, M., and T. S. Galloway. (2015). Ingestion of nanoplastics and microplastics by Pacific oyster larvae. *Environmental Science & Technology, 49*(24), 14625–14632.

Colleye, O., L. Kever, D. Lecchini, L. Berten, and E. Parmentier. (2016). Auditory evoked potential audiograms in post-settlement stage individuals of coral reef fishes. *Journal of Experimental Marine Biology and Ecology, 483*, 1–9.

Collin, S. P., and D. Whitehead. (2004). The functional roles of passive electroreception in non-electric fishes. *Animal Biology, 54*(1), 1–25.

Compagno, L. J. V. (1984). *FAO species catalogue. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 2. Carcharhiniformes* (FAO Fisheries Synopsis No. 125). Tiburon, CA: San Francisco State University.

Coombs, S., and J. C. Montgomery. (1999). The Enigmatic Lateral Line System. In R. R. Fay & A. N. Popper (Eds.), *Comparative Hearing: Fish and Amphibians* (pp. 319–362). New York, NY: Springer-Verlag.

Corcoran, A., M. Dornback, B. Kirkpatrick, and A. Jochens. (2013). *A Primer on Gulf of Mexico Harmful Algal Blooms*. College Station, TX: Gulf of Mexico Alliance and the Gulf of Mexico Coastal Ocean Observing System.

Costa-Pierce, B. A. (2012). Aquaculture in Ancient Hawaii. *Bioscience, 37*(5), 320–331.

Couturier, L. I. E., A. D. Marshall, F. R. A. Jaine, T. Kashiwagi, S. J. Pierce, K. A. Townsend, S. J. Weeks, M. B. Bennett, and A. J. Richardson. (2012). Biology, ecology and conservation of the Mobulidae. *Journal of Fish Biology, 80*, 1075–1119.

Cox, B. S., A. M. Dux, M. C. Quist, and C. S. Guy. (2012). Use of a seismic air gun to reduce survival of nonnative lake trout embryos: A tool for conservation? *North American Journal of Fisheries Management, 32*(2), 292–298.

Craig, M. T., J. H. Choat, B. Ferreira, A. A. Bertoncini, L. Rocha, and P. C. Heemstra. (2008). *Mycteroperca jordani*. *The IUCN Red List of Threatened Species 2008: e.T14049A4386048.* Retrieved from http://www.iucnredlist.org/details/14049/0.

Crain, C. M., B. S. Halpern, M. W. Beck, and C. V. Kappel. (2009). Understanding and Managing Human Threats to the Coastal Marine Environment. In R. S. Ostfeld & W. H. Schlesinger (Eds.), *The Year in Ecology and Conservation Biology, 2009* (pp. 39–62). Oxford, United Kingdom: Blackwell Publishing.

Dahl, P. H., C. A. de Jong, and A. N. Popper. (2015). The underwater sound field from impact pile driving and its potential effects on marine life. *Acoustics Today, 11*(2), 18–25.

Daly-Engel, T. S., K. D. Seraphin, K. N. Holland, J. P. Coffey, H. A. Nance, R. J. Toonen, and B. W. Bowen. (2012). Global phylogeography with mixed-marker analysis reveals male-mediated dispersal in the endangered scalloped hammerhead shark (*Sphyrna lewini*). *PLoS ONE, 7*(1), e29986.

Danner, G. R., J. Chacko, and F. Brautigam. (2009). Voluntary ingestion of soft plastic fishing lures affects brook trout growth in the laboratory. *North American Journal of Fisheries Management, 29*(2), 352–360.

Dantas, D. V., M. Barletta, and M. F. da Costa. (2012). The seasonal and spatial patterns of ingestion of polyfilament nylon fragments by estuarine drums (Sciaenidae). *Environmental Science and Pollution Research, 19*(2), 600–606.

Davison, P., and R. G. Asch. (2011). Plastic ingestion by mesopelagic fishes in the North Pacific Subtropical Gyre. *Marine Ecological Progress Series, 432*, 173–180.

De Robertis, A., and N. O. Handegard. (2013). Fish avoidance of research vessels and the efficacy of noise-reduced vessels: A review. *ICES Journal of Marine Science, 70*(1), 34–45.

Deakos, M. H., J. D. Baker, and L. Bejder. (2011). Characteristics of a manta ray *Manta alfredi* population off Maui, Hawaii, and implications for management. *Marine Ecology Progress Series, 429*, 245–260.

Debusschere, E., B. De Coensel, A. Bajek, D. Botteldooren, K. Hostens, J. Vanaverbeke, S. Vandendriessche, K. Van Ginderdeuren, M. Vincx, and S. Degraer. (2014). *In situ* mortality experiments with juvenile sea bass (*Dicentrarchus labrax*) in relation to impulsive sound levels caused by pile driving of windmill foundations. *PLoS ONE, 9*(10), e109280.

Defenders of Wildlife. (2015a). *A Petition to List the Oceanic Whitetip Shark (Carcharhinus longimanus) as an Endangered, or Alternatively as a Threatened, Species Pursuant to the Endangered Species Act and for the Concurrent Designation of Critical Habitat*. Denver, CO: Defenders of Wildlife.

Defenders of Wildlife. (2015b). *A Petition to List the Giant Manta Ray (Manta birostris), Reef Manta Ray (Manta alfredi), and Caribbean Manta Ray (Manta c.f. birostris) as Endangered, or Alternatively as Threatened, Species Pursuant to the Endangered Species Act and for the Concurrent Designation of Critical Habitat*. Denver, CO: Defenders of Wildlife.

Dempster, T., and M. Taquet. (2004). Fish aggregation device (FAD) research: Gaps in current knowledge and future direction for ecological studies. *Reviews in Fish Biology and Fisheries, 14*(1), 21–42.

Deng, X., H. J. Wagner, and A. N. Popper. (2011). The inner ear and its coupling to the swim bladder in the deep-sea fish *Antimora rostrata* (Teleostei: Moridae). *Deep Sea Research Part 1, Oceanographic Research Papers, 58*(1), 27–37.

Deng, X., H. J. Wagner, and A. N. Popper. (2013). Interspecific variations of inner ear structure in the deep-sea fish family Melamphaidae. *The Anatomical Record, 296*(7), 1064–1082.

Dennis, M. H. (2015). *Status Review of the Gulf Grouper (Mycteroperca jordani)*. Silver Spring, MD: National Marine Fisheries Service, West Coast Protected Resources Division.

Derraik, J. G. B. (2002). The pollution of the marine environment by plastic debris: A review. *Marine Pollution Bulletin, 44*, 842–852.

Doksaeter, L., O. R. Godo, N. O. Handegard, P. H. Kvadsheim, F. P. A. Lam, C. Donovan, and P. J. O. Miller. (2009). Behavioral responses of herring (*Clupea harengus*) to 1–2 and 6–7 kHz sonar signals and killer whale feeding sounds. *The Journal of the Acoustical Society of America, 125*(1), 554–564.

Doksaeter, L., N. O. Handegard, O. R. Godo, P. H. Kvadsheim, and N. Nordlund. (2012). Behavior of captive herring exposed to naval sonar transmissions (1.0–1.6 kHz) throughout a yearly cycle. *The Journal of the Acoustical Society of America, 131*(2), 1632–1642.

Doropoulos, C., S. Ward, G. Diaz-Pulido, O. Hoegh-Guldberg, and P. J. Mumby. (2012). Ocean acidification reduces coral recruitment by disrupting intimate larval-algal settlement interactions. *Ecology Letters, 15*(4), 338–346.

Drazen, J. C., and B. A. Seibel. (2007). Depth-related trends in metabolism of benthic and benthopelagic deep-sea fishes. *Limnology and Oceanography, 52*(5), 2306–2316.

Dufour, F., H. Arrizabalaga, X. Irigoien, and J. Santiago. (2010). Climate impacts on albacore and bluefin tunas migrations phenology and spatial distribution. *Progress In Oceanography, 86*(1–2), 283–290.

Duncan, K. M., and K. N. Holland. (2006). Habitat use, growth rates and dispersal patterns of juvenile scalloped hammerhead sharks, *Sphyrna lewini,* in a nursery habitat. *Marine Ecology Progress Series, 312*, 211–221.

Ebert, D. A., S. Fowler, and M. Dando. (2015). *A Pocket Guide to Sharks of the World*. Princeton, NJ and Oxford, United Kingdom: Princeton University Press.

Edds-Walton, P. L., and J. J. Finneran. (2006). *Evaluation of Evidence for Altered Behavior and Auditory Deficits in Fishes Due to Human-Generated Noise Sources*. (Technical Report 1939). San Diego, CA: SPAWAR Systems Center.

Edwards, M. H., S. M. Shjegstad, R. Wilkens, J. C. King, G. Carton, D. Bala, B. Bingham, M. C. Bissonnette, C. Briggs, N. S. Bruso, R. Camilli, M. Cremer, R. B. Davis, E. H. DeCarlo, C. DuVal, D. J. Fornari, I. Kaneakua-Pia, C. D. Kelley, S. Koide, C. L. Mah, T. Kerby, G. J. Kurras, M. R. Rognstad, L. Sheild, J. Silva, B. Wellington, and M. V. Woerkom. (2016). The Hawaii undersea military munitions assessment. *Deep Sea Research Part II: Topical Studies in Oceanography, 128*, 4–13.

Engås, A., O. A. Misund, A. V. Soldal, B. Horvei, and A. Solstad. (1995). Reactions of penned herring and cod to playback of original, frequency-filtered and time-smoothed vessel sound. *Fisheries Research, 22*(3), 243–254.

Enger, P. S. (1981). *Frequency Discrimination in Teleosts–Central or Peripheral?* New York, NY: Springer-Verlag.

Environmental Sciences Group. (2005). *Canadian Forces Maritime Experimental and Test Ranges: Environmental Assessment Update 2005*. Kingston, Canada: Environmental Sciences Group, Royal Military College.

Eschmeyer, W. N., and J. D. Fong. (2016). *Species by Family/Subfamily in the Catalog of Fishes*. San Francisco, CA: California Academy of Sciences.

Eschmeyer, W. N., and J. D. Fong. (2017). *Catalog of Fishes*. San Francisco, CA: California Academy of Sciences. Retrieved from http://researcharchive.calacademy.org/research/ichthyology/catalog/SpeciesByFamily.asp.

Estrada, J. A., A. N. Rice, M. E. Lutcavage, and G. B. Skomal. (2003). Predicting trophic position in sharks of the north-west Atlantic ocean using stable isotope analysis. *Journal of the Marine Biological Association of the United Kingdom, 83*, 1347–1350.

Fabry, V. J., B. A. Seibel, R. A. Feely, and J. C. Orr. (2008). Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science, 65*(3), 414–432.

Faulkner, S. G., W. M. Tonn, M. Welz, and D. R. Schmitt. (2006). Effects of explosives on incubating lake trout eggs in the Canadian Arctic. *North American Journal of Fisheries Management, 26*(4), 833–842.

Faulkner, S. G., M. Welz, W. M. Tonn, and D. R. Schmitt. (2008). Effects of simulated blasting on mortality of rainbow trout eggs. *Transactions of the American Fisheries Society, 137*(1), 1–12.

Feist, B. E., J. J. Anderson, and R. Miyamoto. (1992). *Potential Impacts of Pile Driving on Juvenile Pink (Oncorhynchus gorbuscha) and Chum (O. keta) Salmon Behavior and Distribution*. Seattle, WA: University of Washington.

Felix, A., M. E. Stevens, and R. L. Wallace. (1995). Unpalatability of a colonial rotifer, *Sinantherina socialis,* to small zooplanktivorous fishes. *Invertebrate Biology, 114*(2), 139–144.

Felline, S., R. Caricato, A. Cutignano, S. Gorbi, M. G. Lionetto, E. Mollo, F. Regoli, and A. Terlizzi. (2012). Subtle effects of biological invasions: Cellular and physiological responses of fish eating the exotic pest *Caulerpa racemosa*. *PLoS ONE, 7*(6), e38763.

Fewtrell, J. L., and R. D. McCauley. (2012). Impact of air gun noise on the behaviour of marine fish and squid. *Marine Pollution Bulletin, 64*(5), 984–993.

Fields, R. D. (2007). The Shark's Electric Sense: An astonishingly sensitive detector of electric fields helps sharks zero in on prey. *Scientific American, 297*(2), 75–81.

Fitch, J. E., and P. H. Young. (1948). *Use and Effect of Explosives in California Coastal Waters*. Sacramento, CA: California Division Fish and Game.

Fitzpatrick, J. L., J. K. Desjardins, K. A. Stiver, R. Montgomerie, and S. Balshine. (2006). Male reproductive suppression in the cooperatively breeding fish *Neolamprologus pulcher*. *Behavioural Ecology, 17*, 25–33.

Foderaro, L. W. (2015). Group Petitions to Save a Prehistoric Fish From Modern Construction. *New York Times*. Retrieved from http://www.nytimes.com/2015/07/22/nyregion/group-petitions-to-save-a-prehistoric-fish-from-modern-construction.html?_r=0.

Food and Agriculture Organization of the United Nations. (2005). *Review of the State of World Marine Fishery Resources*. Rome, Italy: Food and Agriculture Organization Fisheries Department, Fishery Resources Division, Marine Resources Service.

Food and Agriculture Organization of the United Nations. (2009). *The State of World Fisheries and Aquaculture*. Rome, Italy: Food and Agriculture Organization Fisheries Department, Fishery Resources Division, Marine Resources Service.

Food and Agriculture Organization of the United Nations. (2013). *Report of the Fourth FAO Expert Advisory Panel for the Assessment of Proposals to Amend Appendices I and II of CITES Concerning Commercially-Exploited Aquatic Species*. Rome, Italy: Food and Agriculture Organization Fisheries Department, Fishery Resources Division, Marine Resources Service.

Frisk, G. V. (2012). Noiseonomics: The relationship between ambient noise levels in the sea and global economic trends. *Scientific Reports, 2*(437).

Froese, R., and D. Pauly. (2010). *FishBase*. Version (01/2010). Retrieved from www.fishbase.org.

Froese, R., and D. Pauly. (2016). *FishBase*. Version (01/2016). Retrieved from www.fishbase.org.

Gaither, M. R., G. Aeby, M. Vignon, Y. Meguro, M. Rigby, C. Runyon, R. J. Toonen, C. L. Wood, and B. W. Bowen. (2013). An invasive fish and the time-lagged spread of its parasite across the Hawaiian archipelago. *PLoS ONE, 8*(2), e56940.

Gaspin, J. B. (1975). *Experimental Investigations of the Effects of Underwater Explosions on Swimbladder Fish, I: 1973 Chesapeake Bay Tests*. Silver Spring, MD: Naval Surface Weapons Center, White Oak Laboratory.

Gaspin, J. B., G. B. Peters, and M. L. Wisely. (1976). *Experimental Investigations of the Effects of Underwater Explosions on Swimbladder Fish*. Silver Spring, MD: Naval Ordnance Lab.

Germanov, E. S., and A. D. Marshall. (2014). Running the gauntlet: Regional movement patterns of *Manta alfredi* through a complex of parks and fisheries. *PLoS ONE, 9*(10), e110071.

Gill, A. B. (2005). Offshore renewable energy: Ecological implications of generating electricity in the coastal zone. *Journal of Applied Ecology, 42*, 605–615.

Gitschlag, G. R., M. J. Schirripa, and J. E. Powers. (2000). *Estimation of Fisheries Impacts Due to Underwater Explosives Used to Sever and Salvage Oil and Gas Platforms in the U.S. Gulf of Mexico: Final Report*. Washington, DC: U.S. Department of the Interior.

Goatley, C. H. R., and D. R. Bellwood. (2009). Morphological structure in a reef fish assemblage. *Coral Reefs, 28*(2), 449–457.

Goertner, J. F. (1978). *Dynamical Model for Explosion Injury to Fish*. Dalgren, VA: U.S. Department of the Navy, Naval Surface Weapons Center.

Goertner, J. F., M. L. Wiley, G. A. Young, and W. W. McDonald. (1994). *Effects of Underwater Explosions on Fish Without Swimbladders*. Silver Spring, MD: Naval Surface Warfare Center.

Goetz, S., M. B. Santos, J. Vingada, D. C. Costas, A. G. Villanueva, and G. J. Pierce. (2015). Do pingers cause stress in fish? An experimental tank study with European sardine, *Sardina pilchardus* (Walbaum, 1792) (Actinopterygii, Clupeidae), exposed to a 70 kHz dolphin pinger. *Hydrobiologia, 749*(1), 83–96.

Goncalves, R., M. Scholze, A. M. Ferreira, M. Martins, and A. D. Correia. (2008). The joint effect of polycyclic aromatic hydrocarbons on fish behavior. *Environmental Research, 108*, 204–213.

Good, T. P., R. S. Waples, and P. Adams, (Eds.). (2005). *Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead*. Washington, DC: U.S. Department of Commerce.

Govoni, J. J., L. R. Settle, and M. A. West. (2003). Trauma to juvenile pinfish and spot inflicted by submarine detonations. *Journal of Aquatic Animal Health, 15*, 111–119.

Govoni, J. J., M. A. West, L. R. Settle, R. T. Lynch, and M. D. Greene. (2008). Effects of Underwater Explosions on Larval Fish: Implications for a Coastal Engineering Project. *Journal of Coastal Research, 2*, 228–233.

Graham, R. T., M. J. Witt, D. W. Castellanos, F. Remolina, S. Maxwell, B. J. Godley, and L. A. Hawkes. (2012). Satellite tracking of manta rays highlights challenges to their conservation. *PLoS ONE, 7*(5), e36834.

Greer, C. D., P. V. Hodson, Z. Li, T. King, and K. Lee. (2012). Toxicity of crude oil chemically dispersed in a wave tank to embryos of Atlantic herring (*Clupea harengus*). *Environmental Toxicology and Chemistry, 31*, 1–10.

Haedrich, R. L. (1996). Deep-water fishes: Evolution and adaptation in the earth's largest living spaces. *Journal of Fish Biology, 49*(Supplement A), 40–53.

Halpern, B., S. Walbridge, K. A. Selkoe, C. V. Kappel, F. Micheli, C. D'Agrosa, J. F. Bruno, K. S. Casey, C. Ebert, H. E. Fox, R. Fujita, D. Heinemann, H. S. Lenihan, E. M. P. Madin, M. T. Perry, E. R. Selig, M.

Spalding, R. S. Steneck, and R. Watson. (2008a). A global map of human impact on marine ecosystems. *Science, 319*(5865), 948–952.

Halpern, B. S., K. L. McLeod, A. A. Rosenberg, and L. B. Crowder. (2008b). Managing for cumulative impacts in ecosystem-based management through ocean zoning. *Ocean & Coastal Management, 51*(3), 203–211.

Halvorsen, M. B., B. M. Casper, C. M. Woodley, T. J. Carlson, and A. N. Popper. (2011). *Hydroacoustic Impacts on Fish from Pile Installation* (Research Results Digest). Washington, DC: National Cooperative Highway Research Program, Transportation Research Board, National Academy of Sciences.

Halvorsen, M. B., B. M. Casper, F. Matthews, T. J. Carlson, and A. N. Popper. (2012a). Effects of exposure to pile-driving sounds on the lake sturgeon, Nile tilapia and hogchoker. *Proceedings of the Royal Society B: Biological Sciences, 279*(1748), 4705–4714.

Halvorsen, M. B., B. M. Casper, C. M. Woodley, T. J. Carlson, and A. N. Popper. (2012b). Threshold for onset of injury in Chinook salmon from exposure to impulsive pile driving sounds. *PLoS ONE, 7*(6), e38968.

Halvorsen, M. B., D. G. Zeddies, W. T. Ellison, D. R. Chicoine, and A. N. Popper. (2012c). Effects of mid-frequency active sonar on hearing in fish. *The Journal of the Acoustical Society of America, 131*(1), 599–607.

Halvorsen, M. B., D. G. Zeddies, D. Chicoine, and A. N. Popper. (2013). Effects of low-frequency naval sonar exposure on three species of fish. *The Journal of the Acoustical Society of America, 134*(2), EL205–210.

Handegard, N. O., K. Michalsen, and D. Tjøstheim. (2003). Avoidance behaviour in cod (*Gadus morhua*) to a bottom-trawling vessel. *Aquatic Living Resources, 16*(3), 265–270.

Handegard, N. O., A. D. Robertis, G. Rieucau, K. Boswell, G. J. Macaulay, and J. M. Jech. (2015). The reaction of a captive herring school to playbacks of a noise-reduced and a conventional research vessel. *Canadian Journal of Fisheries and Aquatic Sciences, 72*(4), 491–499.

Hansen, L. P., and M. L. Windsor. (2006). Interactions between aquaculture and wild stocks of Atlantic salmon and other diadromous fish species: Science and management, challenges and solutions. *ICES Journal of Marine Science, 63*(7), 1159–1161.

Hare, J. A., W. E. Morrison, M. W. Nelson, M. M. Stachura, E. J. Teeters, R. B. Griffis, M. A. Alexander, J. D. Scott, L. Alade, R. J. Bell, A. S. Chute, K. L. Curti, T. H. Curtis, D. Kircheis, J. F. Kocik, S. M. Lucey, C. T. McCandless, L. M. Milke, D. E. Richardson, E. Robillard, H. J. Walsh, M. C. McManus, K. E. Marancik, and C. A. Griswold. (2016). A vulnerability assessment of fish and invertebrates to climate change on the Northeast U.S. Continental Shelf. *PLoS ONE, 11*(2), 1–30.

Hartwell, S. I., C. H. Hocutt, and W. F. van Heukelem. (1991). Swimming response of menhaden (*Brevoortia tyrannus*) to electromagnetic pulses. *Journal of Applied Ichthyology, 7*(2), 90–94.

Hastings, M., A. Popper, J. Finneran, and P. Lanford. (1996). Effects of low-frequency underwater sound on hair cells of the inner ear and lateral line of the teleost fish *Astronotus ocellatus*. *The Journal of the Acoustical Society of America, 99*(3), 1759–1766.

Hastings, M. C. (1991). *Effects of underwater sound on bony fishes*. Paper presented at the 122nd Meeting of the Acoustical Society of America. Houston, TX.

Hastings, M. C. (1995). *Physical effects of noise on fishes.* Paper presented at the 1995 International Congress on Noise Control Engineering. Newport Beach, CA.

Hastings, M. C., and A. N. Popper. (2005). *Effects of Sound on Fish* (Final Report #CA05-0537). Sacramento, CA: California Department of Transportation.

Hawkins, A. D., and A. D. F. Johnstone. (1978). The hearing of the Atlantic salmon, *Salmo salar*. *Journal of Fish Biology, 13*, 655–673.

Hawkins, A. D., L. Roberts, and S. Cheesman. (2014). Responses of free-living coastal pelagic fish to impulsive sounds. *The Journal of the Acoustical Society of America, 135*(5), 3101–3116.

Hawkins, A. D., A. E. Pembroke, and A. N. Popper. (2015). Information gaps in understanding the effects of noise on fishes and invertebrates. *Reviews in Fish Biology and Fisheries, 25*, 39–64.

Hazen, E. L., S. Jorgensen, R. R. Rykaczewski, S. J. Bograd, D. G. Foley, I. D. Jonsen, S. A. Shaffer, J. P. Dunne, D. P. Costa, L. B. Crowder, and B. A. Block. (2012). Predicted habitat shifts of Pacific top predators in a changing climate. *Nature Climate Change, 3*(3), 234–238.

Helfman, G. S., B. B. Collette, D. E. Facey, and B. W. Bowen. (2009). *The Diversity of Fishes: Biology, Evolution, and Ecology* (2nd ed.). Malden, MA: Wiley-Blackwell.

Herbert-Read, J. E., L. Kremer, R. Bruintjes, A. N. Radford, and C. C. Ioannou. (2017). Anthropogenic noise pollution from pile-driving disrupts the structure and dynamics of fish shoals. *Proceedings of the Royal Society of London B: Biological Sciences, 284*(1863).

Heuer, R. M., and M. Grosell. (2014). Physiological impacts of elevated carbon dioxide and ocean acidification on fish. *American Journal of Physiology - Regulatory, Integrative and Comparative Physiology, 307*(9), 1061–1084.

Higgs, D. M. (2005). Auditory cues as ecological signals for marine fishes. *Marine Ecology Progress Series, 287*, 278–281.

Higgs, D. M., and C. A. Radford. (2013). The contribution of the lateral line to 'hearing' in fish. *The Journal of Experimental Biology, 216*(Pt 8), 1484–1490.

Hildebrand, J. (2009). Anthropogenic and natural sources of ambient noise in the ocean. *Marine Ecology Progress Series, 395*, 5–20.

Hoffmayer, E. R., J. S. Franks, W. B. Driggers, and P. W. Howey. (2013). Diel vertical movements of a scalloped hammerhead, *Sphyrna lewini*, in the northern Gulf of Mexico. *Bulletin of Marine Science, 89*(2), 551–557.

Holt, D. E., and C. E. Johnston. (2014). Evidence of the Lombard effect in fishes. *Behavioral Ecology, 25*(4), 819–826.

Hore, P. J. (2012). Are biochemical reactions affected by weak magnetic fields? *Proceedings of the National Academy of Sciences, 109*(5), 1357–1358.

Horst, T. J. (1977). Use of Leslie Matrix for assessing environmental-impact with an example for a fish population. *Transactions of the American Fisheries Society, 106*(3), 253–257.

Hoss, D. E., and L. R. Settle. (1990). *Ingestion of plastics by teleost fishes* (Proceedings of the Second International Conference on Marine Debris). Honolulu, HI: US Department of Commerce, National Oceanic and Atmospheric Administration.

Hovey, T. E. (2004). Current Status of Southern Steelhead/Rainbow Trout in San Mateo Creek, California. *California Fish and Game Bulletin, 90*(3), 140–154.

Hubbs, C., and A. Rechnitzer. (1952). Report on experiments designed to determine effects of underwater explosions on fish life. *California Fish and Game, 38*, 333–366.

Huntingford, F., C. Adams, V. A. Braithwaite, S. Kadri, T. G. Pottinger, P. Sandoe, and J. F. Turnball. (2006). Review paper: Current issues in fish welfare. *Journal of Fish Biology, 70*(4), 1311–1316.

Huveneers, C., P. J. Rogers, J. M. Semmens, C. Beckmann, A. A. Kock, B. Page, and S. D. Goldsworthy. (2013). Effects of an electric field on white sharks: In situ testing of an electric deterrent. *PLoS ONE, 8*(5), e62730.

Iafrate, J. D., S. L. Watwood, E. A. Reyier, D. M. Scheidt, G. A. Dossot, and S. E. Crocker. (2016). Effects of pile driving on the residency and movement of tagged reef fish. *PLoS ONE, 11*(11), e0163638.

Illingworth and Rodkin, Inc. (2015). *Underwater and Airborne Acoustic Monitoring for the U.S. Navy Elevated Causeway Removal at the JEB Little Creek Naval Station: 10–11 September 2015* (Naval Facilities Engineering Command Atlantic under HDR Environmental, Operations and Construction, Inc.). Petaluma, CA: Illingworth & Rodkin, Inc.

Illingworth and Rodkin, Inc. (2017). *Pile-Driving Noise Measurements at Atlantic Fleet Naval Installations: 28 May 2013–28 April 2016. Final Report*. Petaluma, CA: HDR.

Ingvarsdottir, A., C. Bjorkblom, E. Ravagnan, B. F. Godal, M. Arnberg, D. L. Joachim, and S. Sanni. (2012). Effects of different concentrations of crude oil on first feeding larvae of Atlantic herring (*Clupea harengus*). *Journal of Marine Systems, 93*, 69–76.

Inman, M. (2005). Fish moved by warming waters. *Science, 308*, 937.

Inter-American Tropical Tuna Commission. (2015). *Tunas, Billfishes, and Other Species in the Eastern Pacific Ocean in 2014* (Fishery Status Report). La Jolla, CA: Inter-American Tropical Tuna Commission.

Intergovernmental Panel on Climate Change. (2014). *IPCC Fifth Assessment Report*. Geneva, Switzerland: Intergovernmental Panel on Climate Change.

Jackson, G. D., N. G. Buxton, and M. J. A. George. (2000). Diet of the southern opah, *Lampris immaculatus,* on the Patagonian Shelf; the significance of the squid, *Moroteuthis ingens,* and anthropogenic plastic. *Marine Ecology Progress Series, 206*, 261–271.

Jain-Schlaepfer, S., E. Fakan, J. L. Rummer, S. D. Simpson, and M. I. McCormick. (2018). Impact of motorboats on fish embryos depends on engine type. *Conservation Physiology, 6*(1), coy014.

Jensen, J. O. T. (2003). *New Mechanical Shock Sensitivity Units in Support of Criteria for Protection of Salmonid Eggs from Blasting or Seismic Disturbance*. Nanaimo, Canada: Fisheries and Oceans Canada Science Branch Pacific Region, Pacific Biological Station.

Johnstone, R. A., and R. Bshary. (2004). Evolution of spite through indirect reciprocity. *Proceeding of the Royal Society B, 271*, 1917–1922.

Jørgensen, R., N. O. Handegard, H. Gjøsæter, and A. Slotte. (2004). Possible vessel avoidance behaviour of capelin in a feeding area and on a spawning ground. *Fisheries Research, 69*(2), 251–261.

Jørgensen, R., K. K. Olsen, I. B. Falk-Petersen, and P. Kanapthippilai. (2005). *Investigations of Potential Effects of Low Frequency Sonar Signals on Survival, Development and Behaviour of Fish Larvae and Juveniles*. Tromsø, Norway: University of Tromsø, The Norwegian College of Fishery Science.

Joung, S. J., N. F. Chen, H. H. Hsu, and K. M. Liu. (2016). Estimates of life history parameters of the oceanic whitetip shark, *Carcharhinus longimanus*, in the Western North Pacific Ocean. *Marine Biology Research, 12*(7), 758–768.

Kajiura, S. M., and K. N. Holland. (2002). Electroreception in juvenile scalloped hammerhead and sandbar sharks. *The Journal of Experimental Biology, 205*, 3609–3621.

Kalmijn, A. J. (2000). Detection and processing of electromagnetic and near-field acoustic signals in elasmobranch fishes. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences, 355*(1401), 1135–1141.

Kane, A. S., J. Song, M. B. Halvorsen, D. L. Miller, J. D. Salierno, L. E. Wysocki, D. Zeddies, and A. N. Popper. (2010). Exposure of fish to high intensity sonar does not induce acute pathology. *Journal of Fish Biology, 76*(7), 1825–1840.

Kappel, C. V. (2005). Losing pieces of the puzzle: Threats to marine, estuarine, and diadromous species. *Frontiers in Ecology and the Environment, 3*(5), 275–282.

Karlsson, S., and A. C. Albertsson. (1998). Biodegradable polymers and environmental interaction. *Polymer Engineering and Science, 38*(8), 1251–1253.

Kastelein, R. A., S. van der Heul, W. C. Verboom, N. Jennings, J. van der Veen, and D. de Haan. (2008). Startle response of captive North Sea fish species to underwater tones between 0.1 and 64 kHz. *Marine Environmental Research, 65*(5), 369–377.

Kauparinen, A., and J. Merila. (2007). Detecting and managing fisheries-induced evolution. *Trends in Ecology & Evolution, 22*(12), 652–659.

Keevin, T. M., and G. L. Hempen. (1997). *The Environmental Effects of Underwater Explosions with Methods to Mitigate Impacts*. St. Louis, MO: U.S. Army Corps of Engineers.

Keller, A. A., E. L. Fruh, M. M. Johnson, V. Simon, and C. McGourty. (2010). Distribution and abundance of anthropogenic marine debris along the shelf and slope of the U.S. West Coast. *Marine Pollution Bulletin, 60*(5), 692–700.

Keller, A. A., W. W. Wakefield, V. Simon, J. A. Barth, and S. D. Pierce. (2015). Occurrence of demersal fishes in relation to near-bottom oxygen levels within the California Current large marine ecosystem. *Fisheries Oceanography, 24*(2), 162–176.

Kelley, C., G. Carton, M. Tomlinson, and A. Gleason. (2016). Analysis of towed camera images to determine the effects of disposed mustard-filled bombs on the deep water benthic community off south Oahu. *Deep Sea Research Part II: Topical Studies in Oceanography, 128*, 34–42.

Ketchum, J. T., A. Hearn, A. P. Klimley, E. Espinoza, C. Penaherrera, and J. L. Largier. (2014a). Seasonal changes in movements and habitat preferences of the scalloped hammerhead shark (*Sphyrna lewini*) while refuging near an oceanic island. *Marine Biology, 161*(4), 755–767.

Ketchum, J. T., A. Hearn, A. P. Klimley, C. Penaherrera, E. Espinoza, S. Bessudo, G. Soler, and R. Arauz. (2014b). Inter-island movements of scalloped hammerhead sharks (*Sphyrna lewini*) and seasonal connectivity in a marine protected area of the eastern tropical Pacific. *Marine Biology, 161*(4), 939–951.

Kéver, L., O. Colleye, A. Herrel, P. Romans, and E. Parmentier. (2014). Hearing capacities and otolith size in two ophidiiform species (*Ophidion rochei* and *Carapus acus*). *The Journal of Experimental Biology, 217*(Pt 14), 2517–2525.

Kimber, J. A., D. W. Sims, P. H. Bellamy, and A. B. Gill. (2014). Elasmobranch cognitive ability: using electroreceptive foraging behaviour to demonstrate learning, habituation and memory in a benthic shark. *Animal Cognition, 17*(1), 55–65.

Kohler, N. E., and P. A. Turner. (2001). Shark tagging: A review of conventional methods and studies. *Environmental Biology of Fishes, 60*(1–3), 191–223.

Koide, S., J. A. K. Silva, V. Dupra, and M. Edwards. (2016). Bioaccumulation of chemical warfare agents, energetic materials, and metals in deep-sea shrimp from discarded military munitions sites off Pearl Harbor. *Deep Sea Research Part II: Topical Studies in Oceanography, 128*, 53–62.

Koslow, J. A. (1996). Energetic and life-history patterns of deep-sea benthic, benthopelagic and seamount-associated fish. *Journal of Fish Biology, 49*(Supplement A), 54–74.

Kritzler, H., and L. Wood. (1961). Provisional audiogram for the shark, *Carcharhinus leucas*. *Science, 133*(3463), 1480–1482.

Kroeker, K. J., R. L. Kordas, R. Crim, I. E. Hendriks, L. Ramajo, G. S. Singh, C. M. Duarte, and J.-P. Gattuso. (2013). Impacts of ocean acidification on marine organisms: Quantifying sensitivities and interaction with warming. *Global Change Biology, 19*, 1884–1896.

Kujawa, S. G., and M. C. Liberman. (2009). Adding insult to injury: Cochlear nerve degeneration after "temporary" noise-induced hearing loss. *The Journal of Neuroscience, 29*(45), 14077–14085.

Kvadsheim, P. H., and E. M. Sevaldsen. (2005). The potential impact of 1-8 kHz active sonar on stocks of juvenile fish during sonar exercises. In F. Forskningsinstitutt (Ed.), (pp. 1–19). Kjeller, Norway: Norwegian Defence Research Establishment.

Ladich, F. (2008). Sound communication in fishes and the influence of ambient and anthropogenic noise. *Bioacoustics, 17*, 35–37.

Ladich, F., and R. R. Fay. (2013). Auditory evoked potential audiometry in fish. *Reviews in Fish Biology and Fisheries, 23*(3), 317–364.

Ladich, F. (2014). Fish bioacoustics. *Current Opinion in Neurobiology, 28*, 121–127.

Laist, D. W. (1987). Overview of the biological effects of lost and discarded plastic debris in the marine environment. *Marine Pollution Bulletin, 18*(6B), 319–326.

LGL Ltd Environmental Research Associates, Lamont Doherty Earth Observatory, and National Science Foundation. (2008). *Environmental Assessment of a Marine Geophysical Survey by the R/V Melville in the Santa Barbara Channel*. King City, Ontario: La Jolla, CA, Scripps Institution of Oceanography and Arlington, VA, National Science Foundation: Division of Ocean Sciences.

Liberman, M. C. (2016). Noise-induced hearing loss: Permanent versus temporary threshold shifts and the effects of hair cell versus neuronal degeneration. *Advances in Experimental Medicine and Biology, 875*, 1–7.

Lin, H. W., A. C. Furman, S. G. Kujawa, and M. C. Liberman. (2011). Primary neural degeneration in the guinea pig cochlea after reversible noise-induced threshold shift. *Journal of the Association for Research in Otolaryngology, 12*(5), 605–616.

Løkkeborg, S., E. Ona, A. Vold, and A. Salthaug. (2012). Effects of sounds from seismic air guns on fish behavior and catch rates. In A. N. Popper & A. Hawkins (Eds.), *The Effects of Noise on Aquatic Life* (Vol. 730, pp. 415–419). New York, NY: Springer.

Lombarte, A., H. Y. Yan, A. N. Popper, J. C. Chang, and C. Platt. (1993). Damage and regeneration of hair cell ciliary bundles in a fish ear following treatment with gentamicin. *Hearing Research, 66*, 166–174.

Lombarte, A., and A. N. Popper. (1994). Quantitative analyses of postembryonic hair cell addition in the otolithic endorgans of the inner ear of the European hake, *Merluccius merluccius* (Gadiformes, Teleostei). *The Journal of Comparative Neurology, 345*, 419–428.

Lotufo, G. R., W. Blackburn, S. J. Marlborough, and J. W. Fleeger. (2010). Toxicity and bioaccumulation of TNT in marine fish in sediment exposures. *Ecotoxicology and Environmental Safety, 73*(7), 1720–1727.

Love, M. S., and A. York. (2005). A comparison of the fish assemblages associated with an oil/gas pipeline and adjacent seafloor in the Santa Barbara Channel, Southern California Bight. *Bulletin of Marine Science, 77*(1), 101–117.

Løvik, A., and J. M. Hovem. (1979). An experimental investigation of swimbladder resonance in fishes. *The Journal of the Acoustical Society of America, 66*(3), 850–854.

Lundquist, C. J., S. F. Thrush, G. Coco, and J. E. Hewitt. (2010). Interactions between disturbance and dispersal reduce persistence thresholds in a benthic community. *Marine Ecology Progress Series, 413*, 217–228.

Lusher, A. L., C. O'Donnell, R. Officer, and I. O'Connor. (2016). Microplastic interactions with North Atlantic mesopelagic fish. *ICES Journal of Marine Science, 73*(4), 1214–1225.

Macfadyen, G., T. Huntington, and R. Cappell. (2009). *Abandoned, Lost or Otherwise Discarded Fishing Gear*. Rome, Italy: United Nations Environment Programme, Food and Agriculture Organization of the United Nations.

Macpherson, E. (2002). Large-scale species-richness gradients in the Atlantic Ocean. *Proceedings of the Royal Society of Biology, 269*(1501), 1715–1720.

Macreadie, P. I., A. M. Fowler, and D. J. Booth. (2011). Rigs-to-reefs: Will the deep sea benefit from artificial habitat? *Frontiers in Ecology and the Environment, 9*(8), 455–461.

Madaro, A., R. E. Olsen, T. S. Kristiansen, L. O. Ebbesson, T. O. Nilsen, G. Flik, and M. Gorissen. (2015). Stress in Atlantic salmon: Response to unpredictable chronic stress. *The Journal of Experimental Biology, 218*(16), 2538–2550.

Madl, P., and M. Yip. (2000). *Cartilagenous fish: Colloquial Meeting of Chondrichthyes; Essay about the Electric Organ Discharge (EOD)*. Salzburg, Austria. Retrieved from http://biophysics.sbg.ac.at/ray/eod.htm.

Madsen, P. T., M. Wahlberg, J. Tougaard, K. Lucke, and P. Tyack. (2006). Wind turbine underwater noise and marine mammals: Implications of current knowledge and data needs. *Marine Ecology Progress Series, 309*, 279–295.

Mann, D., D. Higgs, W. Tavolga, M. Souza, and A. Popper. (2001). Ultrasound detection by clupeiform fishes. *The Journal of the Acoustical Society of America*, 3048–3054.

Mann, D. A., Z. Lu, and A. N. Popper. (1997). A clupeid fish can detect ultrasound. *Nature, 389*, 341.

Mann, D. A., Z. Lu, M. C. Hastings, and A. N. Popper. (1998). Detection of ultrasonic tones and simulated dolphin echolocation clicks by a teleost fish, the American shad (*Alosa sapidissima*). *The Journal of the Acoustical Society of America, 104*(1), 562–568.

Mann, D. A. (2016). Acoustic Communications in Fishes and Potential Effects of Noise. In A. N. Popper & A. D. Hawkins (Eds.), *The Effects of Noise on Aquatic Life II* (pp. 673–678). New York, NY: Springer.

Marcotte, M. M., and C. G. Lowe. (2008). Behavioral responses of two species of sharks to pulsed, direct current electrical fields: Testing a potential shark deterrent. *Marine Technology Society Journal, 42*(2), 53–61.

Marras, S., R. S. Batty, and P. Domenici. (2012). Information transfer and antipredator maneuvers in schooling herring. *Adaptive Behavior, 20*(1), 44–56.

Marshall, N. J. (1996). Vision and sensory physiology: The lateral line systems of three deep-sea fish. *Journal of Fish Biology, 49*(Supplement A), 239–258.

Martin, B., D. G. Zeddies, B. Gaudet, and J. Richard. (2016). Evaluation of three sensor types for particle motion measurement. *Advances in Experimental Medicine and Biology, 875*, 679–686.

Mato, Y., T. Isobe, H. Takada, H. Kanehiro, C. Ohtake, and T. Kaminuma. (2001). Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. *Environmental Science Technology, 35*, 318–324.

McCartney, B. S., and A. R. Stubbs. (1971). Measurements of the acoustic target strengths of fish in dorsal aspect, including swimbladder resonance. *Journal of Sound and Vibration, 15*(3), 397–420.

McCauley, R. D., and D. H. Cato. (2000). Patterns of fish calling in a nearshore environment in the Great Barrier Reef. *Philosophical Transactions: Biological Sciences, 355*(1401), 1289–1293.

McCauley, R. D., J. Fewtrell, A. J. Duncan, C. Jenner, M.-N. Jenner, J. D. Penrose, R. I. T. Prince, A. Adhitya, J. Murdoch, and K. A. McCabe. (2000). *Marine Seismic Surveys: Analysis and Propagation of Air-gun Signals; and Effects of Air-gun Exposure on Humpback Whales, Sea Turtles, Fishes and Squid*. Bentley, Australia: Centre for Marine Science and Technology.

McCauley, R. D., J. Fewtrell, and A. N. Popper. (2003). High intensity anthropogenic sound damages fish ears. *The Journal of the Acoustical Society of America, 113*(1), 638–642.

McCauley, R. D., and C. S. Kent. (2012). A lack of correlation between air gun signal pressure waveforms and fish hearing damage. *Advances in Experimental Medicine and Biology, 730*, 245–250.

McCormick, M. I., B. J. M. Allan, H. Harding, and S. D. Simpson. (2018). Boat noise impacts risk assessment in a coral reef fish but effects depend on engine type. *Scientific Reports, 8*(1), 3847.

McDonald, M., J. Hildebrand, S. Wiggins, and D. Ross. (2008). A 50 Year comparison of ambient ocean noise near San Clemente Island: A bathymetrically complex coastal region off Southern California. *The Journal of the Acoustical Society of America, 124*(4), 1985–1992.

McEwan, D., and T. A. Jackson. (1996). *Steelhead Restoration and Management Plan for California*. Sacramento, CA: California Department of Fish and Game.

McIver, E. L., M. A. Marchaterre, A. N. Rice, and A. H. Bass. (2014). Novel underwater soundscape: Acoustic repertoire of plainfin midshipman fish. *The Journal of Experimental Biology, 217*(Pt 13), 2377–2389.

McLennan, M. W. (1997). *A Simple Model for Water Impact Peak Pressure and Pulse Width: A Technical Memorandum*. Goleta, CA: Greeneridge Sciences, Inc.

Mensinger, A. F., R. L. Putland, and C. A. Radford. (2018). The effect of motorboat sound on Australian snapper *Pagrus auratus* inside and outside a marine reserve. *Ecology and Evolution, 8*(13), 6438–6448.

Meyer, M., R. R. Fay, and A. N. Popper. (2010). Frequency tuning and intensity coding of sound in the auditory periphery of the lake sturgeon, *Acipenser fulvescens*. *The Journal of Experimental Biology, 213*, 1567–1578.

Miksis-Olds, J. L., and S. M. Nichols. (2015). Is low frequency ocean sound increasing globally? *The Journal of the Acoustical Society of America, 139*(1), 501–511.

Miller, J. D. (1974). Effects of noise on people. *The Journal of the Acoustical Society of America, 56*(3), 729–764.

Miller, M. H., J. Carlson, P. Cooper, D. Kobayashi, M. Nammack, and J. Wilson. (2014). *Status Review Report: Scalloped Hammerhead Shark (Sphyrna lewini)*. Silver Spring, MD: National Marine Fisheries Service, Office of Protected Resources.

Miller, M. H., and C. Klimovich. (2016). *Endangered Species Act Status Review Report: Giant Manta Ray (Manta birostris) and Reef Manta Ray (Manta alfredi).* Silver Spring, MD: National Marine Fisheries Service, Office of Protected Resources.

Mintz, J. D., and R. J. Filadelfo. (2011). *Exposure of Marine Mammals to Broadband Radiated Noise* (Specific Authority N0001-4-05-D-0500). Washington, DC: Center for Naval Analyses.

Mintz, J. D. (2012). *Vessel Traffic in the Hawaii-Southern California and Atlantic Fleet Testing and Training Study Areas*. (CRM D0026186.A2/Final). Alexandria, VA: Center for Naval Analyses.

Mintz, J. D. (2016). *Characterization of Vessel Traffic in the Vicinities of HRC, SOCAL, and the Navy Operating Areas off the U.S. East Coast*. Alexandria, VA: Center for Naval Analyses.

Misund, O. A. (1997). Underwater acoustics in marine fisheries and fisheries research. *Reviews in Fish Biology and Fisheries, 7*, 1–34.

Moore, A., and W. D. Riley. (2009). Magnetic particles associated with the lateral line of the European eel, *Anguilla anguilla*. *Journal of Fish Biology, 74*(7), 1629–1634.

Moore, C. J. (2008). Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. *Environmental Research, 108*(2), 131–139.

Moyle, P. B., and J. J. Cech, Jr. (2004). *Fishes: An Introduction to Ichthyology* (5th ed.). London, United Kingdom: Pearson Educational, Inc.

Mueller-Blenkle, C., P. K. McGregor, A. B. Gill, M. H. Andersson, J. Metcalfe, V. Bendall, P. Sigray, D. Wood, and F. Thomsen. (2010). *Effects of Pile-Driving Noise on the Behaviour of Marine Fish*. London, United Kingdom: COWRIE Ltd.

Munday, P. L., D. L. Dixson, J. M. Donelson, G. P. Jones, M. S. Pratchett, G. V. Devitsina, and K. B. Doving. (2009). Ocean acidification impairs olfactory discrimination and homing ability of a marine fish. *Proceedings of the National Academy of Sciences of the United States of America, 106*(6), 1848–1852.

Musick, J. A., M. M. Harbin, S. A. Berkeley, G. H. Burgess, A. M. Eklund, L. Findley, R. G. Gilmore, J. T. Golden, D. S. Ha, G. R. Huntsman, J. C. McGovern, S. J. Parker, S. G. Poss, E. Sala, T. W. Schmidt, G. R. Sedberry, H. Weeks, and S. G. Wright. (2000). Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (exclusive of Pacific salmonids). *Fisheries, 25*(11), 6–30.

Myrberg, A. A., C. R. Gordon, and A. P. Klimley. (1976). Attraction of free ranging sharks by low frequency sound, with comments on its biological significance. In A. Schuijf & A. D. Hawkins (Eds.), *Sound Reception in Fish*. Amsterdam, Netherlands: Elsevier.

Myrberg, A. A. (1980). Ocean noise and the behavior of marine animals: Relationships and implications. In F. P. Diemer, F. J. Vernberg, & D. Z. Mirkes (Eds.), *Advanced Concepts in Ocean Measurements for Marine Biology* (pp. 461–491). Columbia, SC: University of South Carolina Press.

Myrberg, A. A., Jr., A. Banner, and J. D. Richard. (1969). Shark attraction using a video-acoustic system. *Marine Biology, 2*(3), 264–276.

Myrberg, A. A., Jr., S. J. Ha, S. Walewski, and J. C. Banbury. (1972). Effectiveness of acoustic signals in attracting epipelagic sharks to an underwater sound source. *Bulletin of Marine Science, 22*, 926–949.

Myrberg, A. A., Jr. (2001). The acoustical biology of elasmobranchs. *Environmental Biology of Fishes, 60*, 31–45.

National Geographic. (2016). Information on Deep-vent Eelpouts. Retrieved from http://environment.nationalgeographic.com/environment/habitats/deep-sea-vents/.

National Marine Fisheries Service. (1997). *Endangered and Threatened Species: Listing of Several Evolutionary Significant Units (ESUs) of West Coast Steelhead*. Washington, DC: U.S. Government Publishing Office. Retrieved from https://www.gpo.gov/fdsys/granule/FR-1997-08-18/97-21661.

National Marine Fisheries Service. (2002). Magnuson-Stevens Act provisions; Essential Fish Habitat (EFH)–Final Rule. *Federal Register, 67*(12), 2343–2383.

National Marine Fisheries Service. (2010a). *Cruise Report: Oscar Elton Sette, Cruise SE-10-01 (SE-77)*. Honolulu, HI: Pacific Island Fisheries Science Center.

National Marine Fisheries Service. (2010b). *Steelhead Trout (Oncorhynchus mykiss)*. Silver Spring, MD: National Oceanic and Atmospheric Administration Fisheries Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/fish/steelhead-trout.htm.

National Marine Fisheries Service. (2011). *Petition to List the Scalloped Hammerhead Shark (Sphyrna lewini) Under the U.S. Endangered Species Act Either Worldwide or as One or More Distinct Population Segments*. Silver Spring, MD: National Marine Fisheries Service.

National Marine Fisheries Service. (2012). *Southern California Steelhead Recovery Plan Summary*. Long Beach, CA: Southwest Regional Office.

National Marine Fisheries Service. (2016a). *Status of Stocks 2015* (Annual Report to Congress on the Status of U.S. Fisheries). Silver Spring, MD: National Marine Fisheries Service.

National Marine Fisheries Service. (2016b). *South-Central/Southern California Coast Steelhead Recovery Planning Domain: 5-Year Review: Summary and Evaluation of Southern California Coast Steelhead Distinct Population Segment*. Long Beach, CA: West Coast Region, California Coastal Office.

National Marine Fisheries Service. (2017). *Gulf Grouper (Mycteroperca jordani)*. Retrieved from https://www.fisheries.noaa.gov/species/gulf-grouper.

National Marine Fisheries Service. (2018). *Status of Stocks 2017* (Annual Report to Congress on the Status of U.S. Fisheries). Silver Spring, MD: National Marine Fisheries Service.

National Oceanic and Atmospheric Administration. (2011). *Marine Aquaculture Policy*. Silver Spring, MD: National Oceanic and Atmospheric Administration. Retrieved from https://www.avma.org/Advocacy/National/Federal/Documents/noaa_aquaculture_policy_factsheet2011.pdf.

National Oceanic and Atmospheric Administration. (2014). *Crude oil causes developmental abnormalities in large marine fish: Study shows Deepwater Horizon oil disrupts heart development in tunas*. Retrieved from http://www.noaanews.noaa.gov/stories2014/20140324_dwh_fishimpact.html.

National Oceanic and Atmospheric Administration. (2016a). *Oceanic Whitetip Shark (Carcharhinus longimanus)*. Retrieved from https://www.fisheries.noaa.gov/species/oceanic-whitetip-shark.

National Oceanic and Atmospheric Administration. (2016b). *Harmful Algal Blooms Observing System*. Retrieved from http://habsos.noaa.gov/.

National Oceanic and Atmospheric Administration. (2016c). *Manta rays (Manta spp.)*. Retrieved from https://www.fisheries.noaa.gov/species/giant-manta-ray.

National Oceanic and Atmospheric Administration. (2016d). *About the National Marine Aquaculture Initiative*. Retrieved from http://www.nmfs.noaa.gov/aquaculture/funding/nmai.html.

National Research Council. (1994). *Low-Frequency Sound and Marine Mammals: Current Knowledge and Research Needs*. Washington, DC: The National Academies Press.

National Research Council. (2003). *Ocean Noise and Marine Mammals*. Washington, DC: The National Academies Press.

Nedelec, S. L., S. D. Simpson, E. L. Morley, B. Nedelec, and A. N. Radford. (2015). Impacts of regular and random noise on the behaviour, growth and development of larval Atlantic cod (*Gadus morhua*). *Proceedings of the Royal Society B: Biological Sciences, 282*(1817), 1–7.

Nedelec, S. L., J. Campbell, A. N. Radford, S. D. Simpson, and N. D. Merchant. (2016a). Particle motion: The missing link in underwater acoustic ecology. *Methods in Ecology and Evolution, 7*(7), 836–842.

Nedelec, S. L., S. C. Mills, D. Lecchini, B. Nedelec, S. D. Simpson, and A. N. Radford. (2016b). Repeated exposure to noise increases tolerance in a coral reef fish. *Environmental Pollution, 216*, 428–236.

Nedelec, S. L., A. N. Radford, L. Pearl, B. Nedelec, M. I. McCormick, M. G. Meekan, and S. D. Simpson. (2017). Motorboat noise impacts parental behaviour and offspring survival in a reef fish. *Proceedings of the Royal Society of London B: Biological Sciences, 284*(1856).

Neenan, S. T. V., R. Piper, P. R. White, P. Kemp, T. G. Leighton, and P. J. Shaw. (2016). Does Masking Matter? Shipping Noise and Fish Vocalizations. In A. N. Popper & A. D. Hawkins (Eds.), *The Effects of Noise on Aquatic Life II* (pp. 747–754). New York, NY: Springer.

Nelson, D. R., and R. H. Johnson. (1972). Acoustic attraction of Pacific reef sharks: Effect of pulse intermittency and variability. *Comparative Biochemistry and Physiology Part A, 42*, 85–95.

Nelson, J. S., E. J. Crossman, H. Espinosa-Pérez, L. T. Findley, C. R. Gilbert, R. N. Lea, and J. D. Williams. (2004). Common and scientific names of fishes from the United States, Canada, and Mexico. In: *American Fisheries Society Special Publication 29* (6th ed.). Bethesda, MD: American Fisheries Society.

Nelson, J. S. (2006). *Fishes of the World* (4th ed.). Hoboken, NJ: John Wiley & Sons.

Nelson, J. S., T. C. Grande, and M. V. H. Wilson. (2016). *Fishes of the World* (5th ed.). Hoboken, NJ: John Wiley & Sons, Inc.

Nemeth, D. J., and C. H. Hocutt. (1990). Acute effects of electromagnetic pulses (EMP) on fish. *Journal of Applied Ichthyology, 6*(1), 59–64.

Neo, Y. Y., J. Seitz, R. A. Kastelein, H. V. Winter, C. Ten Cate, and H. Slabbekoorn. (2014). Temporal structure of sound affects behavioural recovery from noise impact in European seabass. *Biological Conservation, 178*, 65–73.

Neo, Y. Y., E. Ufkes, R. A. Kastelein, H. V. Winter, C. Ten Cate, and H. Slabbekoorn. (2015). Impulsive sounds change European seabass swimming patterns: Influence of pulse repetition interval. *Marine Pollution Bulletin, 97*(1–2), 111–117.

Netburn, A. N., and J. A. Koslow. (2015). Dissolved oxygen as a constraint on daytime deep scattering layer depth in the Southern California current ecosystem. *Deep-Sea Research I, 104*, 149–158.

Newman, M. C. (1998). Uptake, biotransformation, detoxification, elimination, and accumulation. *Fundamentals of Ecotoxicology* (pp. 25). Chelsea, MI: Ann Arbor Press.

Nichols, T. A., T. W. Anderson, and A. Širović. (2015). Intermittent noise induces physiological stress in a coastal marine fish. *PLoS ONE, 10*(9), e0139157.

Nix, P., and P. Chapman. (1985). *Monitoring of underwater blasting operations in False Creek, British Columbia.* Paper presented at the Proceedings of the Workshop on Effects of Explosive Use in the Marine Environment. Ottawa, Canada.

O'Connell, C. P., D. C. Abel, P. H. Rice, E. M. Stroud, and N. C. Simuro. (2010). Responses of the southern stingray (*Dasyatis americana*) and the nurse shark (*Ginglymostoma cirratum*) to permanent magnets. *Marine and Freshwater Behaviour and Physiology, 43*(1), 63–73.

O'Keeffe, D. J. (1984). *Guidelines for Predicting the Effects of Underwater Explosions on Swimbladder Fish*. Dahlgren, VA: Naval Surface Weapons Center.

O'Keeffe, D. J., and G. A. Young. (1984). *Handbook on the Environmental Effects of Underwater Explosions*. Silver Spring, MD: U.S. Navy, Naval Surface Weapons Center (Code R14).

Ocean Conservancy. (2010a). *BP Oil Disaster: Relief, Restoration, and Reform*. *Our Work.* Retrieved from http://www.oceanconservancy.org/our-work/bp-oil-spill/.

Ocean Conservancy. (2010b). *Trash Travels: From Our Hands to the Sea, Around the Globe, and Through Time* (International Coastal Cleanup Report). Washington, DC: Ocean Conservancy.

Ohman, M. C., P. Sigray, and H. Westerberg. (2007). Offshore windmills and the effects of electromagnetic fields on fish. *Ambio, 36*(8), 630–633.

Ormerod, S. J. (2003). Current issues with fish and fisheries: Editor's overview and introduction. *Journal of Applied Ecology, 40*(2), 204–213.

Ospina-Alvarez, N., and F. Piferrer. (2008). Temperature-dependent sex determination in fish revisited: Prevalence, a single sex ratio response pattern, and possible effects of climate change. *PLoS ONE, 3*(7), 1–11.

Pacific Shark Research Center. (2017). *Basking Sharks*. Retrieved from https://psrc.mlml.calstate.edu/current-research/citizen-science/basking-shark/about-basking-sharks/.

Parin, N. V. (1984). Oceanic ichthyologeography: An attempt to review the distribution and origin of pelagic and bottom fishes outside continental shelves and neritic zones. *Fourth Congress of European Ichthyologists, 35*(1), 5–41.

Pauly, D., and M. L. Palomares. (2005). Fishing down marine food web: It is far more pervasive than we thought. *Bulletin of Marine Science, 76*(2), 197–211.

Paxton, A. B., J. C. Taylor, D. P. Nowacek, J. Dale, E. Cole, C. M. Voss, and C. H. Peterson. (2017). Seismic survey noise disrupted fish use of a temperate reef. *Marine Policy, 78*, 68–73.

Paxton, J. R., and W. N. Eshmeyer. (1998). *Encyclopedia of Fishes* (2nd ed.). San Diego, CA: Academic Press.

Payne, N. L., D. E. van der Meulen, I. M. Suthers, C. A. Gray, and M. D. Taylor. (2015). Foraging intensity of wild mulloway *Argyrosomus japonicus* decreases with increasing anthropogenic disturbance. *Journal of Marine Biology, 162*(3), 539–546.

Pearson, W. H., J. R. Skalski, and C. I. Malme. (1992). Effects of sounds from a geophysical survey device on behavior of captive rockfish (*Sebastes* spp.). *Canadian Journal of Fisheries and Aquatic Sciences, 49*, 1343–1356.

Pena, H., N. O. Handegard, and E. Ona. (2013). Feeding herring schools do not react to seismic air gun surveys. *ICES Journal of Marine Science, 70*(6), 1174–1180.

Pepper, C. B., M. A. Nascarella, and R. J. Kendall. (2003). A review of the effects of aircraft noise on wildlife and humans, current control mechanisms, and the need for further study. *Environmental Management, 32*(4), 418–432.

Perry, A. L., P. J. Low, J. R. Ellis, and J. D. Reynolds. (2005). Climate change and distribution shifts in marine fishes. *Science, 308*, 1912–1914.

Peterson, W., J. Fisher, J. Peterson, C. Morgan, B. Burke, and K. Fresh. (2014). Applied Fisheries Oceanography: Ecosystem Indicators of Ocean Conditions Inform Fisheries Management in the California Current. *Oceanography, 27*(4), 80–89.

Pew Oceans Commission. (2003). *America's Living Oceans: Charting a Course for Sea Change*. Arlington, VA: Pew Oceans Commission.

Pickering, A. D. (1981). *Stress and Fish*. New York, NY: Academic Press.

Pitcher, T. J. (1995). The impact of pelagic fish behavior on fisheries. *Scientia Marina, 59*(3–4), 295–306.

Popper, A., D. Plachta, D. Mann, and D. Higgs. (2004). Response of clupeid fish to ultrasound: A review. *ICES Journal of Marine Science, 61*(7), 1057–1061.

Popper, A. N., and B. Hoxter. (1984). Growth of a fish ear: 1. Quantitative analysis of sensory hair cell and ganglion cell proliferation. *Hearing Research, 15*, 133–142.

Popper, A. N. (2003). Effects of anthropogenic sounds on fishes. *Fisheries, 28*(10), 24–31.

Popper, A. N., R. R. Fay, C. Platt, and O. Sand. (2003). Sound detection mechanisms and capabilities of teleost fishes. In S. P. Collin & N. J. Marshall (Eds.), *Sensory Processing in Aquatic Environment*. New York, NY: Springer-Verlag.

Popper, A. N., M. E. Smith, P. A. Cott, B. W. Hanna, A. O. MacGillivray, M. E. Austin, and D. A. Mann. (2005). Effects of exposure to seismic airgun use on hearing of three fish species. *The Journal of the Acoustical Society of America, 117*(6), 3958–3971.

Popper, A. N., T. J. Carlson, A. D. Hawkins, B. L. Southall, and R. L. Gentry. (2006). *Interim Criteria for Injury of Fish Exposed to Pile Driving Operations: A White Paper*. Olympia, WA: Washington State Department of Transportation.

Popper, A. N., M. B. Halvorsen, A. Kane, D. L. Miller, M. E. Smith, J. Song, P. Stein, and L. E. Wysocki. (2007). The effects of high-intensity, low-frequency active sonar on rainbow trout. *The Journal of the Acoustical Society of America, 122*(1), 623–635.

Popper, A. N. (2008). *Effects of Mid- and High-Frequency Sonars on Fish*. Newport, RI: Naval Undersea Warfare Center Division.

Popper, A. N., and C. R. Schilt. (2008). Hearing and acoustic behavior (basic and applied considerations). In J. F. Webb, R. R. Fay, & A. N. Popper (Eds.), *Fish Bioacoustics*. New York, NY: Springer Science + Business Media, LLC.

Popper, A. N., and M. C. Hastings. (2009a). The effects of human-generated sound on fish. *Integrative Zoology, 4*, 43–52.

Popper, A. N., and M. C. Hastings. (2009b). The effects of anthropogenic sources of sound on fishes. *Journal of Fish Biology, 75*(3), 455–489.

Popper, A. N., and R. R. Fay. (2011). Rethinking sound detection by fishes. *Hearing Research, 273*(1–2), 25–36.

Popper, A. N., A. D. Hawkins, R. R. Fay, D. A. Mann, S. M. Bartol, T. J. Carlson, S. Coombs, W. T. Ellison, R. L. Gentry, M. B. Halvorsen, S. Løkkeborg, P. H. Rogers, B. L. Southall, D. G. Zeddies, and W. N. Tavolga. (2014). *ASA S3/SC1.4 TR-2014 Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI*. New York, NY and London, United Kingdom: Acoustical Society of America Press and Springer Briefs in Oceanography.

Popper, A. N., J. A. Gross, T. J. Carlson, J. Skalski, J. V. Young, A. D. Hawkins, and D. G. Zeddies. (2016). Effects of exposure to the sound from seismic airguns on pallid sturgeon and paddlefish. *PLoS ONE, 11*(8), e0159486.

Possatto, F. E., M. Barletta, M. F. Costa, J. A. I. do Sul, and D. V. Dantas. (2011). Plastic debris ingestion by marine catfish: An unexpected fisheries impact. *Marine Pollution Bulletin, 62*(5), 1098–1102.

Powell, M. L., S. I. Kavanaugh, and S. A. Sower. (2005). Current knowledge of hagfish reproduction: Implications for fisheries management. *Integrative & Comparative Biology, 45*, 158–165.

Price, C. B., J. M. Brannon, and S. L. Yost. (1998). *Transformation of RDX and HMX Under Controlled Eh/pH Conditions*. (Technical Report IRRP-98-2). Washington, DC: U.S. Army Corps of Engineers, Waterways Experiment Station.

Price, S. A., S. T. Friedman, and P. C. Wainwright. (2015). How predation shaped fish: The impact of fin spines on body form evolution across teleosts. *Proceedings of the Royal Society B: Biological Sciences, 282*(1819).

Purser, J., and A. N. Radford. (2011). Acoustic noise induces attention shifts and reduces foraging performance in three-spined sticklebacks (*Gasterosteus aculeatus*). *PLoS ONE, 6*(2), e17478.

Radford, A. N., E. Kerridge, and S. D. Simpson. (2014). Acoustic communication in a noisy world: Can fish compete with anthropogenic noise? *Behavioral Ecology, 25*(5), 1022–1030.

Radford, A. N., L. Lebre, G. Lecaillon, S. L. Nedelec, and S. D. Simpson. (2016). Repeated exposure reduces the response to impulsive noise in European seabass. *Global Change Biology, 22*(10), 3349–3360.

Radford, C. A., J. C. Montgomery, P. Caiger, and D. M. Higgs. (2012). Pressure and particle motion detection thresholds in fish: A re-examination of salient auditory cues in teleosts. *The Journal of Experimental Biology, 215*(Pt 19), 3429–3435.

Ramcharitar, J., D. M. Higgs, and A. N. Popper. (2001). Sciaenid inner ears: A study in diversity. *Brain, Behavior and Evolution, 58*, 152–162.

Ramcharitar, J., and A. N. Popper. (2004). Masked auditory thresholds in sciaenid fishes: A comparative study. *The Journal of the Acoustical Society of America, 116*(3), 1687–1691.

Ramcharitar, J., D. Higgs, and A. Popper. (2006). Audition in sciaenid fishes with different swim bladder-inner ear configurations. *The Journal of the Acoustical Society of America, 119*(1), 439–443.

Ramirez-Macias, D., M. Meekan, R. De La Parra-Venegas, F. Remolina-Suarez, M. Trigo-Mendoza, and R. Vazquez-Juarez. (2012). Patterns in composition, abundance and scarring of whale sharks *Rhincodon typus* near Holbox Island, Mexico. *Journal of Fish Biology, 80*, 1401–1416.

Raven, J., K. Caldeira, H. Elderfield, O. Hoegh-Guldberg, P. Liss, U. Riebesell, J. Sheperd, C. Turley, A. Watson, R. Heap, R. Banes, and R. Quinn. (2005). *Ocean acidification due to increasing atmospheric carbon dioxide*. London, United Kingdom: The Royal Society.

Reinhall, P. G., and P. H. Dahl. (2011). Underwater Mach wave radiation from impact pile driving: Theory and observation. *The Journal of the Acoustical Society of America, 130*(3), 1209–1216.

Remage-Healey, L., D. P. Nowacek, and A. H. Bass. (2006). Dolphin foraging sounds suppress calling and elevate stress hormone levels in a prey species, the Gulf toadfish. *The Journal of Experimental Biology, 209*(Pt 22), 4444–4451.

Reshetiloff, K. (2004). *Chesapeake Bay: Introduction to an Ecosystem*. (EPA 903-R-04-003 and CBP/TRS 232/00). Washington, DC: Environmental Protection Agency.

Restore the Gulf. (2010). *America's Gulf Coast: A Long Term Recovery Plan After the Deepwater Horizon Oil Spill*. Washington, DC: U.S. Environmental Protection Agency.

Rex, M. A., and R. J. Etter. (1998). Bathymetric patterns of body size: Implications for deep-sea biodiversity. *Deep-Sea Research Part II-Topical Studies in Oceanography, 45*, 103–127.

Reynolds, J. D., N. K. Dulvy, N. B. Goodwin, and J. A. Hutchings. (2005). Biology of extinction risk in marine fishes. *Proceedings of the Royal Society B: Biological Sciences, 272*(1579), 2337–2344.

Rice, J., and S. Harley. (2012). *Stock Assessment of Oceanic Whitetip Sharks in the Western and Central Pacific Ocean.* Paper presented at the Western and Central Pacific Fisheries Commission Meeting, Busan, Republic of Korea.

Rickel, S., and A. Genin. (2005). Twilight transitions in coral reef fish: The input of light-induced changes in foraging behaviour. *Animal Behaviour, 70*(1), 133–144.

Rigg, D. P., S. C. Peverell, M. Hearndon, and J. E. Seymour. (2009). Do elasmobranch reactions to magnetic fields in water show promise for bycatch mitigation? *Marine and Freshwater Research, 60*(9), 942–948.

Roberts, L., R. Perez-Dominguez, and M. Elliott. (2016). Use of baited remote underwater video (BRUV) and motion analysis for studying the impacts of underwater noise upon free ranging fish and implications for marine energy management. *Marine Pollution Bulletin, 112*(1–2), 75–85.

Rochman, C. M., E. Hoh, T. Kurobe, and S. J. Teh. (2013). Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. *Scientific Reports, 3*, 3263.

Rochman, C. M., A. Tahir, S. L. Williams, D. V. Baxa, R. Lam, J. T. Miller, F. Teh, S. Werorilangi, and S. J. Teh. (2015). Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption. *Nature, 5*, 14340–14350.

Roessig, J. M., C. M. Woodley, J. J. Cech, Jr., and L. J. Hansen. (2004). Effects of global climate change on marine and estuarine fishes and fisheries. *Reviews in Fish Biology and Fisheries, 14*(2), 251–275.

Rosen, G., and G. R. Lotufo. (2010). Fate and effects of composition B in multispecies marine exposures. *Environmental Toxicology and Chemistry, 9999*(12), 1–8.

Rostad, A., S. Kaartvedt, T. A. Klevjer, and W. Melle. (2006). Fish are attracted to vessels. *ICES Journal of Marine Science, 63*(8), 1431–1437.

Rowat, D., M. G. Meekan, U. Engelhardt, B. Pardigon, and M. Vely. (2007). Aggregations of juvenile whale sharks (*Rhincodon typus*) in the Gulf of Tadjoura, Djibouti. *Environmental Biology of Fishes, 80*(4), 465–472.

Ruggerone, G. T., S. Goodman, and R. Miner. (2008). *Behavioral Response and Survival of Juvenile Coho Salmon Exposed to Pile Driving Sounds*. Seattle, WA: Natural Resources Consultants, Inc., and Robert Miner Dynamic Testing, Inc.

Sabates, A., M. P. Olivar, J. Salat, I. Palomera, and F. Alemany. (2007). Physical and biological processes controlling the distribution of fish larvae in the NW Mediterranean. *Progress in Oceanography, 74*(2–3), 355–376.

Sabet, S. S., K. Wesdorp, J. Campbell, P. Snelderwaard, and H. Slabbekoorn. (2016). Behavioural responses to sound exposure in captivity by two fish species with different hearing ability. *Animal Behaviour, 116*, 1–11.

Scholik, A. R., and H. Y. Yan. (2001). Effects of underwater noise on auditory sensitivity of a cyprinid fish. *Hearing Research, 152*(1–2), 17–24.

Scholik, A. R., and H. Y. Yan. (2002a). Effects of boat engine noise on the auditory sensitivity of the fathead minnow, *Pimephales promelas*. *Environmental Biology of Fishes, 63*, 203–209.

Scholik, A. R., and H. Y. Yan. (2002b). The effects of noise on the auditory sensitivity of the bluegill sunfish, *Lepomis macrochirus*. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 133*(1), 43–52.

Schwartz, A. L. (1985). The behavior of fishes in their acoustic environment. *Environmental Biology of Fishes, 13*(1), 3–15.

Schwartz, F. J. (1989). *Zoogeography and Ecology of Fishes Inhabiting North Carolina's Marine Waters to Depths of 600 Meters*. Silver Spring, MD: National Oceanic and Atmospheric Administration.

Schwarz, A. B., and G. L. Greer. (1984). Responses of Pacific herring, *Clupea harengus pallasi*, to some underwater sounds. *Canadian Journal of Fisheries and Aquatic Science, 41*, 1183–1192.

Settle, L. R., J. J. Govoni, M. D. Greene, M. A. West, R. T. Lynch, and G. Revy. (2002). *Investigation of Impacts of Underwater Explosions on Larval and Early Juvenile Fishes*. Beaufort, NC: Center for Coastal Fisheries and Habitat Research.

Shah, A. A., F. Hasan, A. Hameed, and S. Ahmed. (2008). Biological degradation of plastics: A comprehensive review. *Biotechnology Advances, 26*(3), 246–265.

Shane, M. A. (2001). Records of Mexican barracuda, *Sphyraena ensis*, and scalloped hammerhead, *Sphyrna lewini*, from Southern California associated with elevated water temperatures. *Bulletin of the Southern California Academy of Sciences 100*, 160–166.

Sierra-Flores, R., T. Atack, H. Migaud, and A. Davie. (2015). Stress response to anthropogenic noise in Atlantic cod *Gadus morhua* L. *Aquacultural Engineering, 67*, 67–76.

Simpson, S. D., J. Purser, and A. N. Radford. (2015). Anthropogenic noise compromises antipredator behaviour in European eels. *Global Change Biology, 21*(2), 586–593.

Simpson, S. D., A. N. Radford, S. L. Nedelec, M. C. Ferrari, D. P. Chivers, M. I. McCormick, and M. G. Meekan. (2016). Anthropogenic noise increases fish mortality by predation. *Nature Communications, 7*, 10544.

Sisneros, J. A., and A. H. Bass. (2003). Seasonal plasticity of peripheral auditory frequency sensitivity. *The Journal of Neuroscience, 23*(3), 1049–1058.

Sivle, L. D., P. H. Kvadsheim, M. A. Ainslie, A. Solow, N. O. Handegard, N. Nordlund, and F. P. A. Lam. (2012). Impact of naval sonar signals on Atlantic herring (*Clupea harengus*) during summer feeding. *ICES Journal of Marine Science, 69*(6), 1078–1085.

Sivle, L. D., P. H. Kvadsheim, and M. A. Ainslie. (2014). Potential for population-level disturbance by active sonar in herring. *ICES Journal of Marine Science, 72*(2), 558–567.

Sivle, L. D., P. H. Kvadsheim, and M. Ainslie. (2016). Potential population consequences of active sonar disturbance in Atlantic herring: Estimating the maximum risk. *Advances in Experimental Medicine and Biology, 875*, 217–222.

Slabbekoorn, H., N. Bouton, I. van Opzeeland, A. Coers, C. ten Cate, and A. N. Popper. (2010). A noisy spring: The impact of globally rising underwater sound levels on fish. *Trends in Ecology and Evolution, 25*(7), 419–427.

Slotte, A., K. Hansen, J. Dalen, and E. Ona. (2004). Acoustic mapping of pelagic fish distribution and abundance in relation to seismic shooting area off the Norwegian west coast. *Fisheries Research, 67*, 143–150.

Smith, M. E., A. S. Kane, and A. N. Popper. (2004a). Acoustical stress and hearing sensitivity in fishes: Does the linear threshold shift hypothesis hold water? *The Journal of Experimental Biology, 207*, 3591–3602.

Smith, M. E., A. S. Kane, and A. N. Popper. (2004b). Noise-induced stress response and hearing loss in goldfish (*Carassius auratus*). *The Journal of Experimental Biology, 207*(3), 427–435.

Smith, M. E., A. B. Coffin, D. L. Miller, and A. N. Popper. (2006). Anatomical and functional recovery of the goldfish (*Carassius auratus*) ear following noise exposure. *The Journal of Experimental Biology, 209*(21), 4193–4202.

Smith, M. E., and R. R. Gilley. (2008). Testing the equal energy hypothesis in noise-exposed fishes. *Bioacoustics, 17*(1–3), 343–345.

Smith, S. H., and D. E. Marx, Jr. (2016). De-facto marine protection from a Navy bombing range: Farallon de Medinilla, Mariana Archipelago, 1997 to 2012. *Marine Pollution Bulletin, 102*(1), 187–198.

Snieszko, S. F. (1978). Control of Fish Diseases. *Marine Fisheries Review, 40*(3), 65–68.

Song, J., A. Mathieu, R. F. Soper, and A. N. Popper. (2006). Structure of the inner ear of bluefin tuna, *Thunnus thynnus*. *Journal of Fish Biology, 68*, 1767–1781.

Song, J., D. A. Mann, P. A. Cott, B. W. Hanna, and A. N. Popper. (2008). The inner ears of northern Canadian freshwater fishes following exposure to seismic air gun sounds. *The Journal of the Acoustical Society of America, 124*(2), 1360–1366.

South Atlantic Fishery Management Council. (2011). *Dolphin Fish*. Retrieved from http://www.safmc.net/FishIDandRegs/FishGallery/DolphinFish/tabid/284/Default.aspx.

Speed, C. W., M. G. Meekan, D. Rowat, S. J. Pierce, A. D. Marshall, and C. J. A. Bradshaw. (2008). Scarring patterns and relative mortality rates of Indian Ocean whale sharks. *Journal of Fish Biology, 72*(6), 1488–1503.

Sprague, M. W., and J. J. Luczkovich. (2004). Measurement of an individual silver perch, *Bairdiella chrysoura,* sound pressure level in a field recording. *The Journal of the Acoustical Society of America, 116*(5), 3186–3191.

Stadler, J. H., and D. P. Woodbury. (2009). *Assessing the effects to fishes from pile driving: Application of new hydroacoustic criteria*. Paper presented at the Inter-Noise 2009: Innovations in Practical Noise Control. Ottawa, Canada.

Stevens, J. D. (2007). Whale shark (*Rhincodon typus*) biology and ecology: A review of the primary literature. *Fisheries Research, 84*(1), 4–9.

Stuhmiller, J. H., Y. Y. Phillips, and D. R. Richmong. (1991). The Physics and Mechanisms of Primary Blast Injury. In D. P. J. R. Zatchuck, R. F. Bellamy, and C. M. Quick (Ed.), *Textbook of Military Medicine. Part I. Warfare, Weapons, and the Casualty* (Vol. 5, pp. 241–270). Washington, D.C.: TMMM Publications.

Sverdrup, A., E. Kjellsby, P. G. Krüger, R. Fløysand, F. R. Knudsen, P. S. Enger, G. Serck-Hanssen, and K. B. Helle. (1994). Effects of experimental seismic shock on vasoactivity of arteries, integrity of the vascular endothelium and on primary stress hormones of the Atlantic salmon. *Journal of Fish Biology, 45*(6), 973–995.

Swisdak, M. M., Jr. (1978). *Explosion Effects and Properties Part II–Explosion Effects in Water*. (NSWC/WOL/TR-76-116). Dahlgren, VA and Silver Spring, MD: Naval Surface Weapons Center.

Swisdak, M. M., Jr., and P. E. Montanaro. (1992). *Airblast and Fragmentation Hazards Produced by Underwater Explosions*. Silver Spring, MD: Naval Surface Warfare Center.

Swope, B., and J. McDonald. (2013). *Copper-Based Torpedo Guidance Wire: Applications and Environmental Considerations*. San Diego, CA: Space and Naval Warfare Systems Command Center Pacific.

Tavolga, W. N. (1974). Signal/noise ratio and the critical band in fishes. *The Journal of the Acoustical Society of America, 55*(6), 1323–1333.

The Shark Trust. (2017). *Basking Shark Project: Human Impacts*. Retrieved from http://www.sharktrust.org/en/basking_shark_human_impacts.

Tyler, H. R., Jr., and W. G. Pearcy. (1975). The Feeding Habits of Three Species of Lanternfishes (Family Myctophidae) off Oregon, USA. *Marine Biology, 32*, 7–11.

U.S. Department of the Air Force. (1997). *Environmental Effects of Self-Protection Chaff and Flares*. Langley Air Force Base, VA: U.S. Air Force, Headquarters Air Combat Command.

U.S. Department of the Navy. (1999). *Environmental Effects of RF Chaff: A Select Panel Report to the Undersecretary of Defense for Environmental Security*. Washington, DC: U.S. Department of the Navy, Naval Research Laboratory.

U.S. Department of the Navy. (2001a). *Overseas Environmental Assessment (OEA) for Cape Cod TORPEDO EXERCISE (TORPEX) in Fall 2001*. Arlington, VA: Undersea Weapons Program Office.

U.S. Department of the Navy. (2001b). *Airborne Mine Neutralization System (AMNS) Inert Target Tests: Environmental Assessment and Overseas Environmental Assessment*. Panama City, FL: Coastal Systems Station.

U.S. Department of the Navy. (2001c). *Final Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS) for the Shock Trial of the USS WINSTON S. CHURCHILL (DDG 81)*. Washington, DC: U.S. Department of the Navy.

U.S. Department of the Navy. (2005). *Final Environmental Assessment and Overseas Environmental Assessment for Organic Airborne and Surface Influence Sweep Mission Tests*. Washington, DC: Airborne Mine Defense Program Office, Program Executive Office: Littoral and Mine Warfare.

U.S. Department of the Navy. (2012). *Ecosystem Technical Report for the Atlantic Fleet Training and Testing (AFTT) Draft Environmental Impact Statement*. Arlington, VA: Naval Facilities Engineering Command, Atlantic Division. Retrieved from http://www.warcosts.net/wp-content/uploads/us-navy/317BA_1_2012_AFTT_U.S._Navy_Atlantic_Fleet_Training_Testing_Ecosystem_Final_Technical_Report_April_13_2012.pdf.

U.S. Department of the Navy. (2013). *Military Expended Material Shrimp Fisheries Study in the U.S. South Atlantic and Eastern Gulf of Mexico*. Newport, RI: Naval Undersea Warfare Center Division.

U.S. Environmental Protection Agency. (2004). *Regional Analysis Document for Cooling Water Intake Structues-CWA 316(b), Phase II-Large existing electric generating plants*.

University of Hawaii. (2010). *Hawaii Undersea Military Munitions Assessment, Final Investigation Report HI-05, South of Pearl Harbor, Oahu, HI*. Honolulu, HI: University of Hawaii at Manoa.

Voellmy, I. K., J. Purser, D. Flynn, P. Kennedy, S. D. Simpson, and A. N. Radford. (2014a). Acoustic noise reduces foraging success in two sympatric fish species via different mechanisms. *Animal Behaviour, 89*, 191–198.

Voellmy, I. K., J. Purser, S. D. Simpson, and A. N. Radford. (2014b). Increased noise levels have different impacts on the anti-predator behaviour of two sympatric fish species. *PLoS ONE, 9*(7), e102946.

Wainwright, P. C., and B. A. Richard. (1995). Predicting patterns of prey use from morphology of fishes. *Environmental Biology of Fishes, 44*, 97–113.

Wang, W. X., and P. S. Rainbow. (2008). Comparative approaches to understand metal bioaccumulation in aquatic animals. *Comparative Biochemistry and Physiology, Part C, 148*(4), 315–323.

Ward-Paige, C. A., D. M. Keith, B. Worm, and H. K. Lotze. (2012). Recovery potential and conservation options for elasmobranchs. *Journal of Fish Biology, 80*(5), 1844–1869.

Wardle, C. S. (1986). Fish behaviour and fishing gear. In T. J. Pitcher (Ed.), *The Behavior of Teleost Fishes* (pp. 463–495). Baltimore, MD: The Johns Hopkins University Press.

Wardle, C. S., T. J. Carter, G. G. Urquhart, A. D. F. Johnstone, A. M. Ziolkowski, G. Hampson, and D. Mackie. (2001). Effects of seismic air guns on marine fish. *Continental Shelf Research, 21*, 1005–1027.

Warrant, E. J., and N. A. Locket. (2004). Vision in the deep sea. *Biological Reviews, 79*, 671–712.

Webb, J. F., J. C. Montgomery, and J. Mogdans. (2008). Bioacoustics and the Lateral Line of Fishes. In J. F. Webb, R. R. Fay, & A. N. Popper (Eds.), *Fish Bioacoustics* (pp. 145–182). New York, NY: Springer.

Wedemeyer, G. A., B. A. Barton, and D. J. McLeay. (1990). Stress and acclimation. In C. B. Schreck & P. B. Moyle (Eds.), *Methods for Fish Biology* (pp. 451–489). Bethesda, MD: American Fisheries Society.

Wiley, M. L., J. B. Gaspin, and J. F. Goertner. (1981). Effects of underwater explosions on fish with a dynamical model to predict fishkill. *Ocean Science and Engineering, 6*(2), 223–284.

Wilson, D., R. Billings, R. Oommen, B. Lange, J. Marik, S. McClutchey, and H. Perez. (2010). *Year 2008 Gulfwide Emission Inventory Study: Draft Report*. Gulf of Mexico OCS Region: Bureau of Ocean Energy Management, Regulation and Enforcement.

Wootton, E. C., A. P. Woolmer, C. L. Vogan, E. C. Pope, K. M. Hamilton, and A. F. Rowley. (2012). Increased disease calls for a cost-benefits review of marine reserves. *PLoS ONE, 7*(12), e51615.

Wright, D. G. (1982). *A Discussion Paper on the Effects of Explosives on Fish and Marine Mammals in the Waters of the Northwest Territories* (Canadian Technical Report of Fisheries and Aquatic Sciences). Winnipeg, Canada: Western Region Department of Fisheries and Oceans.

Wright, K. J., D. M. Higgs, A. J. Belanger, and J. M. Leis. (2008). Auditory and olfactory abilities of larvae of the Indo-Pacific coral trout *Plectropomus leopardus* (Lacepède) at settlement. *Journal of Fish Biology, 72*(10), 2543–2556.

Wright, K. J., D. M. Higgs, D. H. Cato, and J. M. Leis. (2010). Auditory sensitivity in settlement-stage larvae of coral reef fishes. *Coral Reefs, 29*, 235–243.

Wysocki, L. E., and F. Ladich. (2005). Hearing in fishes under noise conditions. *Journal of the Association for Research in Otolaryngology, 6*(1), 28–36.

Wysocki, L. E., J. P. Dittami, and F. Ladich. (2006). Ship noise and cortisol secretion in European freshwater fishes. *Biological Conservation, 128*, 501–508.

Wysocki, L. E., J. W. Davidson, III, M. E. Smith, A. S. Frankel, W. T. Ellison, P. M. Mazik, A. N. Popper, and J. Bebak. (2007). Effects of aquaculture production noise on hearing, growth, and disease resistance of rainbow trout, *Oncorhynchus mykiss*. *Aquaculture, 272*, 687–697.

Yasugi, M., and M. Hori. (2016). Predominance of parallel- and cross-predation in anglerfish. *Marine Ecology, 37*(3), 576–587.

Yeh, J. (2008). *Depth Zonation of Deep-Sea Megafaunal Scavengers of the Hawaiian Islands.* (Thesis for a Masters of Science in Oceanography). University of Hawaii, Honolulu, HI.

Yelverton, J. T., D. R. Richmond, W. Hicks, K. Saunders, and E. R. Fletcher. (1975). *The Relationship between Fish Size and Their Response to Underwater Blast*. Washington, DC: Defense Nuclear Agency.

Yelverton, J. T., and D. R. Richmond. (1981). *Underwater Explosion Damage Risk Criteria for Fish, Birds, and Mammals.* Paper presented at the 102nd Meeting of the Acoustical Society of America. Miami Beach, FL.

Yender, R. A., J. Michel, and R. Hoff. (2010). *Oil Spills in Coral Reefs: Planning & Response Considerations*. Silver Spring, MD: National Oceanic and Atmospheric Administration.

Young, C. N., J. Carlson, C. Hutt, D. Kobayashi, C. T. McCandless, and J. Wraith. (2016). *Status review report: Oceanic whitetip shark (Carcharhinius longimanus)* (Final Report to the National Marine Fisheries Service, Office of Protected Resources). Silver Spring, MD: National Marine Fisheries Service & National Oceanic and Atmospheric Administration.

Zelick, R., D. A. Mann, and A. N. Popper. (1999). Acoustic communication in fishes and frogs. In R. R. Fay & A. N. Popper (Eds.), *Comparative Hearing: Fish and Amphibians* (pp. 363–411). New York, NY: Springer-Verlag.