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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 (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. Because of the immense Study Area and the broad range of Navy training and testing activities in the Proposed Action (Tables 2.8-1 through 2.8-5), this chapter is very lengthy. Therefore, Section 3.0 addresses issues that apply to many or all of the resources. The resource sections refer back to subsections in Section 3.0 for the general information contained here.

Section 3.0.1 (Regulatory Framework) presents the regulatory framework for the analyses of the resources in Chapter 3. It briefly describes each law, executive order, and directive used to develop the analyses. Other laws and regulations that may apply to this EIS/OEIS, but that were not specifically used in the analysis, are listed in Chapter 6 (Additional Regulatory Considerations). Section 3.0.2 (Data Sources and Best Available Data) lists the sources of data used in the analysis.

The Study Area covers a broad range of ecosystems where Navy training and testing is proposed, so Section 3.0.3 (Ecological Characterization of the Study Area) describes areas known as large marine ecosystems and open ocean areas. The Study Area contains large portions of two large marine ecosystems (the California Current and the Insular Pacific-Hawaiian) and one open ocean area (the North Pacific Subtropical Gyre). Figure 3.0-1 is an overview map of the entire Study Area overlain with the Navy's range complexes and major current systems in the Pacific Ocean. In addition to these descriptions, Section 3.0.3 presents information on ocean bathymetry, currents, and fronts. These topics have general applicability to the resources analyzed.

One of the major issues addressed in this Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS) is the effects of noise on biological resources. The topic of acoustics can be very complicated to the general reader, so Section 3.0.4 (Acoustic and Explosives Primer) presents a primer on sound in water and in air. The primer explains how sound propagates through air and water; defines terms used in the analysis; and describes the physical properties of sound, metrics used to characterize sound exposure, and frequencies produced during Navy training and testing activities.

Section 3.0.5 (Overall Approach to Analysis) describes a general approach to the analysis. It identifies the resources considered for the analysis, as well as those resources eliminated from further consideration. Each Navy training and testing activity was examined to determine which environmental stressors could adversely impact a resource; these stressors were grouped into categories for ease of presentation (Table 3.0-6). Table 3.0-7 associates the stressor categories with training and testing activities. A detailed description of each stressor category is contained in Section 3.0.5.3 (Identification of Stressors for Analysis). Descriptions of stressors that only apply to one resource are found in the associated resource section. Lastly, the general approach section contains the methods used in the biological resource sections. These methods are also organized by stressor categories.

The sections following Section 3.0 analyze each resource. The physical resources (sediment and water quality and air quality) are presented first (Sections 3.1 and 3.2, respectively). Any potential impacts on

these resources were considered as potential secondary stressors on the remaining resources to be described: marine habitats, marine mammals, sea turtles, seabirds, marine vegetation, marine invertebrates, and fish (Sections 3.3 through 3.9). Following the biological resource sections are human resource sections: cultural, socioeconomics, and public health and safety (Sections 3.10, 3.11, and 3.12).

The Navy has made changes to this Final EIS/OEIS based on comments received during the public comment period. Changes include factual corrections, additions to existing information, and improvements or modifications to the analyses presented in the Draft EIS/OEIS. A summary of public comments received and the Navy's response to these comments is provided in Appendix E (Public Participation). While these comments provided valuable guidance and additional information, none of the changes between the Draft and Final EIS/OEIS resulted in substantive changes to the Proposed Action, alternatives, or the conclusions of the environmental consequences of the Proposed Action.

3.0.1 REGULATORY FRAMEWORK

In accordance with the Council on Environmental Quality regulations for implementing the requirements of the National Environmental Policy Act (NEPA), other planning and environmental review procedures are integrated to the fullest extent possible. This section provides a brief overview of the primary federal statutes (3.0.1.1), executive orders (3.0.1.2), and guidance (3.0.1.3) that form the regulatory framework for the evaluation of resources in Chapter 3 (Affected Environment and Environmental Consequences). This section also describes how each applies to the analysis of environmental consequences. Chapter 6 (Additional Regulatory Considerations) provides a summary listing and status of compliance with the applicable environmental laws, regulations, and executive orders that were considered in preparing this EIS/OEIS. More detailed information on the regulatory framework, including other statutes not listed here, may be presented as necessary in each resource section. Although all the environmental laws, regulations, and executive orders provided in Chapter 6 were evaluated in this EIS/OEIS, some were included in regulatory determinations for resources during the analysis of impacts. More detailed discussions of selected regulations are included below to provide insight into the criteria used in the analyses.

3.0.1.1 Federal Statutes

Abandoned Shipwreck Act

The 1987 Abandoned Shipwreck Act (43 United States Code [U.S.C.] §§ 2101–2106) asserts the federal government's title to any abandoned shipwreck that meets criteria for inclusion in the National Register of Historic Places. The Act stipulates that title to these shipwrecks will be transferred to the appropriate State. States have the responsibility to manage the wrecks and to allow access to the sites by the general public while preserving the historical and environmental integrity of the site for scientific investigation. Abandoned shipwreck means any shipwreck to which title has voluntarily been given up by the owner with the intent of never claiming a right or interest in the vessel in the future and without vesting ownership in any other person. Such shipwrecks ordinarily are treated as being abandoned after the expiration of 30 days from the sinking.

Clean Air Act

The purpose of the Clean Air Act (42 U.S.C. § 7401 et seq.) is to protect and enhance the quality of the nation's air resources to promote the public health and welfare and the productive capacity of its population. To fulfill the act's purpose, federal agencies classify air basins according to their attainment status under the National Ambient Air Quality Standards (40 Code of Federal Regulations [C.F.R.] Part 50) and regulate emissions of criteria pollutants and air toxins to protect the public health and welfare.

Noncriteria 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 (USEPA) identified 188 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 implementation plans for achieving and maintaining the National Ambient Air Quality Standards for criteria pollutants.

Clean Water Act

The Clean Water Act (33 U.S.C. § 1251 et seq.) regulates discharges of pollutants in surface waters of the United States. Section 403 of the Clean Water Act provides for the protection of ocean waters (waters of the territorial seas, the contiguous zone, and the high seas beyond the contiguous zone) from point-source discharges. Under Section 403(a), the USEPA or an authorized state agency may issue a permit for an ocean discharge only if the discharge complies with Clean Water Act guidelines for protection of marine waters. For the HSTT EIS/OEIS, the Proposed Action does not include the analysis of discharges incidental to the normal operation of Navy ships.

Endangered Species Act

The Endangered Species Act (ESA) of 1973 (16 U.S.C. § 1531 et seq.) established protection over and conservation of threatened and endangered species and the ecosystems upon which they depend. An "endangered" species is 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 and National Marine Fisheries Service (NMFS) jointly administer the ESA and are also responsible for the listing of species (designating a species as either threatened or endangered). 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 NMFS or U.S. Fish and Wildlife Service, depending on the jurisdiction (50 C.F.R. § 402.14(a)).

Magnuson-Stevens Fishery Conservation and Management Act and Sustainable Fisheries Act

The Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. § 1801 et seq.) enacted in 1976 and amended by the Sustainable Fisheries Act in 1996, mandates identification and conservation of essential fish habitat. Essential fish habitat is defined as those waters and substrates necessary (required to support a sustainable fishery and the federally managed species) 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.

Marine Mammal Protection Act

The Marine Mammal Protection Act (MMPA) of 1972 (16 U.S.C. § 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 in the global commons (that is,

the high seas) by vessels or persons under U.S. jurisdiction. The term "take," as defined in Section 3 (16 U.S.C. § 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 Marine Mammal Protection Act directs the Secretary of Commerce (Secretary) 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 unmitigatable 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 requirements pertaining to the mitigation, 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. § 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." 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. § 1362(18)(B)(i) and (ii)).

Migratory Bird Treaty Act

The Migratory Bird Treaty Act of 1918 (16 U.S.C. § 703 et seq.) and the Migratory Bird Conservation Act (16 U.S.C. §§ 715–715d, 715e, 715f–715r) of 18 February 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 provides that the Armed Forces may take migratory birds incidental to military readiness activities provided that, for those ongoing or proposed activities that the Armed Forces determine may result in a significant adverse effect on a population of a migratory bird species, the Armed Forces confers and cooperates with the Service to develop and implement appropriate conservation measures to minimize or mitigate such significant adverse effects (50 C.F.R. § 21.15).

National Environmental Policy Act

The Navy prepared this EIS/OEIS in accordance with the President's Council on Environmental Quality regulations implementing NEPA (40 C.F.R. Parts 1500–1508). National Environmental Policy Act (42 U.S.C. §§ 4321–4347) requires federal agencies to prepare an EIS for a proposed action with the potential to significantly affect the quality of the human environment, disclose significant environmental impacts, and inform decision makers and the public of the reasonable alternatives to the proposed action. Based on Presidential Proclamation 5928, issued 27 December 1988, impacts on ocean areas that lie within 12 nautical miles (nm) of land (U.S. territory) are subject to analysis under NEPA.

National Historic Preservation Act

The National Historic Preservation Act of 1966 (16 U.S.C. 470 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.

3.0.1.2 Executive Orders

Executive Order 12114, *Environmental Effects Abroad of Major Federal Actions*

This OEIS has been prepared in accordance with Executive Order (EO) 12114 (44 Federal Register [FR] 1957) and Navy implementing regulations in 32 C.F.R. 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 C.F.R. § 187.3). As used in EO 12114, "environment" means the natural and physical environment and excludes social, economic, and other environments. The EIS and OEIS have been combined into one document, as permitted under NEPA and EO 12114, to reduce duplication.

Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*

Executive Order 13514 (74 FR 52117) was signed in October 2009 to establish an integrated strategy toward sustainability in the federal government and to make reduction of greenhouse gas emissions a priority for federal agencies. The Department of Defense (DoD) developed a Strategic Sustainability Performance Plan that identifies performance-based goals and subgoals, provides a method to meet the goals (including investment strategies), and outlines a plan for reporting on performance. The Strategic Sustainability Performance Plan is included in the analyses in this EIS/OEIS.

Executive Order 13547, *Stewardship of the Ocean, Our Coasts, and the Great Lakes*

Executive Order 13547 (75 FR 43023) was issued in 2010. It is a comprehensive national policy for the stewardship of the ocean, our coasts, and the Great Lakes. This order adopts the recommendations of the Interagency Ocean Policy Task Force and directs executive agencies to implement the recommendations under the guidance of a National Ocean Council. This order establishes a national policy to

- ensure the protection, maintenance, and restoration of the health of ocean, coastal, and Great Lakes ecosystems and resources;
- enhance the sustainability of ocean and coastal economies, preserve our maritime heritage,
- support sustainable uses and access;
- provide for adaptive management to enhance our understanding of and capacity to respond to climate change and ocean acidification; and
- coordinate with our national security and foreign policy interests.

3.0.1.3 Guidance

Department of Defense and Navy Directives and Instructions

Several military communications are included in this EIS/OEIS that establish policy or a plan to govern an action, conduct, or procedure. For example, DoD Directive 4540.1, *Use of Airspace by U.S. Military Aircraft and Firings over the High Seas*, and Chief of Naval Operations Instruction 3770.4A, *Use of Airspace by U.S. Military Aircraft and Firing over the High Seas*, specify procedures for conducting aircraft maneuvers and for firing missiles and projectiles. Other directives and instructions referred to in the EIS/OEIS are specific for a range complex or test range such as the Fleet Area Control and Surveillance Facility San Diego Instruction 3120.1G, which is the *Manual of EASTPAC and MIDPAC Fleet Operating Areas*. Each range complex and test range has its own manual; however, many of the components are similar.

3.0.2 Data Sources and Best Available Data

The Navy used the best available data and information to compile the environmental baseline and environmental consequences evaluated in Chapter 3. In accordance with NEPA, the Administrative Procedure Act of 1946 (5 U.S.C. §§ 551–559), and EO 12114, best available data accepted by the appropriate regulatory and scientific communities were used in the analyses of resources.

Literature searches of journals, books, periodicals, bulletins, and other technical reports were conducted in preparation of this EIS/OEIS. Searches included general queries in the resource areas evaluated to document the environmental baseline and specific queries for analysis of environmental consequences. A wide range of primary literature was used in preparing this EIS/OEIS from federal agencies such as the NMFS, the USEPA, international organizations including the United Nations Educational Scientific and Cultural Organization, state agencies, and nonprofit and nongovernment organizations. Internet searches were conducted, and websites were evaluated for credibility of the source, quality of the information, and relevance of the content to ensure use of the best available information in this document.

3.0.2.1 Geographical Information Systems Data

Table 3.0-1 lists sources of non-Navy Geographical Information System data used in Chapter 3 figures.

Table 3.0-1: Sources of Non-Navy Geographic Information System Data Used to Generate Figures in Chapter 3

Feature/Layer	Applicable Figures	Data Source References
Large Marine Ecosystems	All Chapter 3 figures	(National Oceanic and Atmospheric Administration 2002)
Bathymetry and Ocean Base Map	3.0-1, 3.0-2, 3.0-3, 3.0-4, 3.0-5	(General Bathymetric Chart of the Oceans 2010, Intergovernmental Oceanographic Commission 2009)
Sea Surface Temperature	3.0-7, 3.0-8	(University of Miami Rosenstiel School of Marine and Atmospheric Science et al. 2007)
California Air Basins	3.2-1	(California Air Resources Board 2004)
Critical Habitat	All Critical Habitat Figures	(National Marine Fisheries Service and U. S. Fish and Wildlife Service 2009)
NRHP Eligible or Listed Resources/Sovereign Immunity, Shipwrecks	3.10-1, 3.10-2, 3.10-3, 3.10-4, 3.10-5	(NOAA's Automated Wreck and Obstruction Information System [AWOIS] 2002; Google Earth 2010)
Commercially Used Waterways	3.11-1, 3.11-2	(Vanderbilt Engineering Center for Transportation Operations and Research 2004)
Danger Zones and Restricted Areas	3.11-9	(Title 33-Navigation and Navigable Waters, Chapter II-Corps of Engineers, Department of the Army, Department of Defense, Part 334-Danger Zone and Restricted Area Regulations 2005)

Notes: NOAA = National Oceanic and Atmospheric Administration, U.S. = United States, HAPC = Habitat Area of Particular Concern, AWOIS = Automated Wreck and Obstruction Information System, NRHP = National Register of Historic Places, nm = nautical miles, OCS = Office of Coast Survey

3.0.2.2 Navy Integrated Comprehensive Monitoring Program

Since 2006, the Navy, as well as non-Navy marine mammal scientists and research institutions have conducted scientific monitoring and research in and around ocean areas in the Atlantic and Pacific where the Navy has been training and testing and where it proposes to continue these activities. Data collected from Navy monitoring, scientific research findings, and annual reports provided to NMFS may inform the analysis of impacts on marine mammals for a variety of reasons, including species distribution, habitat use, and evaluation of potential responses to Navy activities. Monitoring is performed using various methods, including visual surveys from surface vessels and aircraft and passive acoustics. Navy monitoring can generally be divided into two types of efforts: (1) collecting long-term data on distribution, abundance, and habitat use patterns within Navy activity areas; and (2) collecting data during individual training or testing activities. Monitoring efforts during anti-submarine warfare and explosive events focus on observing individual animals in the vicinity of the event and documenting behavior and any observable responses. Although these monitoring events are very localized and short-term, over time they will provide valuable information to support the impact analysis.

Most of the training and testing activities the Navy is proposing for the next 5 years are similar if not identical to activities that have been occurring in the same locations for decades. For example, the mid-frequency anti-submarine warfare sonar system on the cruisers, destroyers, and frigates has the same sonar system components in the water as those first deployed in the 1970s. While the signal analysis and computing processes onboard these ships have been upgraded with modern technology, the power and output of the sonar transducer, which puts signals into the water, have not changed. Therefore, the history of past marine mammal observations, research, and monitoring reports remain applicable to the analysis of effects from the proposed future training and testing activities.

3.0.2.2.1 Relevant Data From the Hawaii-Southern California Training and Testing Study Area

In the Hawaii Range Complex portion of the Hawaii-Southern California Training and Testing (HSTT) Study Area between 2006 and 2012, 21 scientific marine mammal surveys were conducted before, during, or after major exercises. In the Southern California and Hawaii Range Complex portions of HSTT from 2009 to 2011, Navy-funded marine mammal monitoring research completed over 5,000 hours of visual survey effort covering more than 65,000 nautical miles, sighted more than 256,000 individual marine mammals, took more than 45,600 digital photos and 36 hours of digital video, attached 70 satellite tracking tags to individual marine mammals, and collected more than 40,000 hours of passive acoustic recordings.

The Navy also co-funded additional visual surveys conducted by the NMFS' Pacific Island Fisheries Science Center and Southwest Fisheries Science Center. Finally, there were an additional 1,532 sightings of an estimated 16,224 marine mammals made and reported by Navy lookouts aboard Navy ships within the HSTT from 2009 to 2012.

Based on this research, monitoring before, during, and after training and testing events since 2006, and the reports that have been submitted to and reviewed by NMFS, the Navy's assessment is that it is unlikely there will be impacts to populations of marine mammals having any long-term consequences as a result of the proposed continuation of training and testing in the ocean areas historically used by the Navy.

This assessment of likelihood is based on four indicators from areas in the Pacific where Navy training and testing has been ongoing for decades: (1) evidence suggesting or documenting increases in the numbers of marine mammals present, (2) examples of documented presence and site fidelity of species and long-term residence by individual animals of some species, (3) use of training and testing areas for breeding and nursing activities, and (4) 6 years of comprehensive monitoring data indicating a lack of any observable effects to marine mammal populations as a result of Navy training and testing activities.[1]

3.0.2.3 Marine Species Density Database

A quantitative analysis of impacts on a species requires data on the abundance and concentration of the species population 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 significant effort to collect and analyze data to produce a usable estimate. NMFS is the primary agency responsible for estimating marine mammal and sea turtle density within the U.S. Exclusive Economic Zone. Other independent researchers often publish density data for key species in specific areas of interest. For example, manatee abundance data is collected by state agencies. Within most of the world's oceans, although some survey effort may have been completed, the required amount of surveys has not been conducted to allow density estimation. To approximate distribution and abundance of species for areas or seasons that have not been surveyed, the Habitat Suitability Index or Relative Environmental Suitability model is used to estimate occurrence based on modeled relationships of where the animals are sighted and the associated environmental variables (i.e., depth, sea surface temperature, etc.).

[1] Monitoring of Navy activities began in July 2006 as a requirement under issuance of an Incidental Harassment Authorization by NMFS for the Rim of the Pacific exercise and has continued to the present for training events in the HRC and SOCAL as well as other monitoring as part of the coordinated efforts under the Navy's ICMP developed in coordination with NMFS and others.

There is no single source of density data for every area of the world, species, and season because of the fiscal costs, resources, and effort involved in providing survey coverage to sufficiently estimate density. Therefore, to characterize the marine species density for large areas such as the Study Area, the Navy compiled data from multiple sources. To compile and structure the most appropriate database of marine species density data, the Navy developed a protocol to select the best available data sources based on species, area, and time (season). Refer to the HSTT EIS website for a technical report describing in detail the process the Navy used to create the marine species density database. The resulting Geographic Information System database includes seasonal density values for every marine mammal and sea turtle species present within the Study Area (U.S. Department of the Navy 2012a).

3.0.3 ECOLOGICAL CHARACTERIZATION OF THE HAWAII-SOUTHERN CALIFORNIA TRAINING AND TESTING STUDY AREA

Navy activities in the marine environment predominately occur within established operating areas (OPAREAs), range complexes, test ranges, ports, and pierside locations, although some occur outside these designated areas. These locations were defined by training and testing requirements and regulated maritime and airspace boundaries. However, the Navy-defined boundaries are not consistent with ecological boundaries 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 more comprehensively assess the potential impacts. The Navy used biogeographical 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 3.0.3.1 (Biogeographic Classifications). Additional ecosystem-related concepts, as well as a discussion of how Navy activities and potential stressors of the Proposed Action fit into the ecosystem, are presented in a separate detailed report titled the *Ecosystem Technical Report for the Hawaii-Southern California Training and Testing Draft Environmental Impact Statement* (U.S. Department of the Navy et al. 2012b). Refer to the HSTT EIS website to review a copy of the technical report.

3.0.3.1 Biogeographic Classifications

For the purposes of this document, the Navy organized and described the resources in coastal waters by large marine ecosystems, where primary productivity is higher than open ocean areas; the Navy organized and described the resources in open ocean areas by main oceanographic features (currents, gyres). Primary productivity is the rate of the formation of organic material from inorganic carbon from solar radiation (e.g., marine vegetation) or chemical reactions.

The development of the large marine ecosystem classification system began in the mid-1980s as a spatial planning tool to address transboundary management issues such as fisheries and pollution (Duda and Sherman 2002). Large marine ecosystems are “relatively large regions on the order of 58,310 square nautical miles (nm^2) or greater, characterized by distinct water depths and bottom features; water features such as tides, currents, and waves; nutrient and food availability; and levels that different organisms occupy in the food chain” (National Oceanic Atmospheric Administration 2010). 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 and Sherman 2002).

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 regional coordination and planning in the United States. However, this task force did not endorse any particular classification system for open ocean areas. Therefore, for this EIS/OEIS, two main oceanographic features are used: the California Current and the North Pacific Subtropical Gyre. The Study Area contains two large marine ecosystems: the California Current and the Insular Pacific-Hawaiian, and one open ocean area: the North Pacific Subtropical Gyre. The two large marine ecosystems and one open ocean area are shown in Figure 3.0-1 and briefly described in Section 3.0.3.1.1 (California Current Large Marine Ecosystem) through Section 3.0.3.1.3 (North Pacific Subtropical Gyre Open Ocean Area).

3.0.3.1.1 California Current Large Marine Ecosystem

The California Current Large Marine Ecosystem encompasses an area of approximately 849,425 square miles (mi.^{2}) (2,200,000 square kilometers [km^2]) (Sherman and Hempel 2009) (Figure 3.0-1). This Large Marine Ecosystem is bordered by the United States and Mexico (Heileman and Mahon 2009). Characteristics of this Large Marine Ecosystem are the temperate climate and strong coastal upwelling (Heileman and Mahon 2009). The effects of variable coastal upwelling, the El Nino Southern Oscillation, and the Pacific Decadal Oscillation in this Large Marine Ecosystem lead to interannual variability (yearly changes) in the productivity of the ecosystem including catch levels of harvest species (Heileman and Mahon 2009). The average primary productivity within this large marine ecosystem is low: less than 150 grams of carbon per square meter per year (g carbon/m^2/year) (Aquarone and Adams 2009). The productivity ranges for some typical global ecosystems are included in Table 3.0-2 for comparison with the values provided for large marine ecosystems.

Table 3.0-2: Net Primary Production for Several Ecosystem Types, for Comparison with the Primary Productivity Values Provided for Each Large Marine Ecosystem

Ecosystems (in descending order of productivity)	Net Primary Productivity g carbon/m^2/year	Large Marine Ecosystems with Equivalent Average Primary Productivity
Salt marsh wetland	4,100–23,000	None in Study Area
Mangrove wetland	3,000–14,800	None in Study Area
Coral reef	1,370–11,000	None in Study Area
Rain forest	2,750–9,600	None in Study Area
Open ocean	5–1,100	California Current Insular Pacific-Hawaiian

Notes: g = grams, m^2 = square meters
Source: Mitsch and Gosselink 1993

3.0.3.1.2 Insular Pacific-Hawaiian Large Marine Ecosystem

The Insular Pacific-Hawaiian Large Marine Ecosystem encompasses an area of approximately 386,102 mi.^{2} (1,000,000 km^2) (Sherman and Hempel 2009). This Large Marine Ecosystem extends 1,500 miles (mi.) (2,414 km) from the Main Hawaiian Islands to the outer Northwestern Hawaiian Islands (Heileman and Mahon 2009) (Figure 3.0-1). This region is characterized by limited ocean nutrients, which leads to high biodiversity but low sustainable yields for fisheries (Heileman and Mahon 2009). 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 g of carbon per m^2/year (Aquarone and Adams 2009). This is comparable to productivity levels associated with the open ocean (Table 3.0-1).

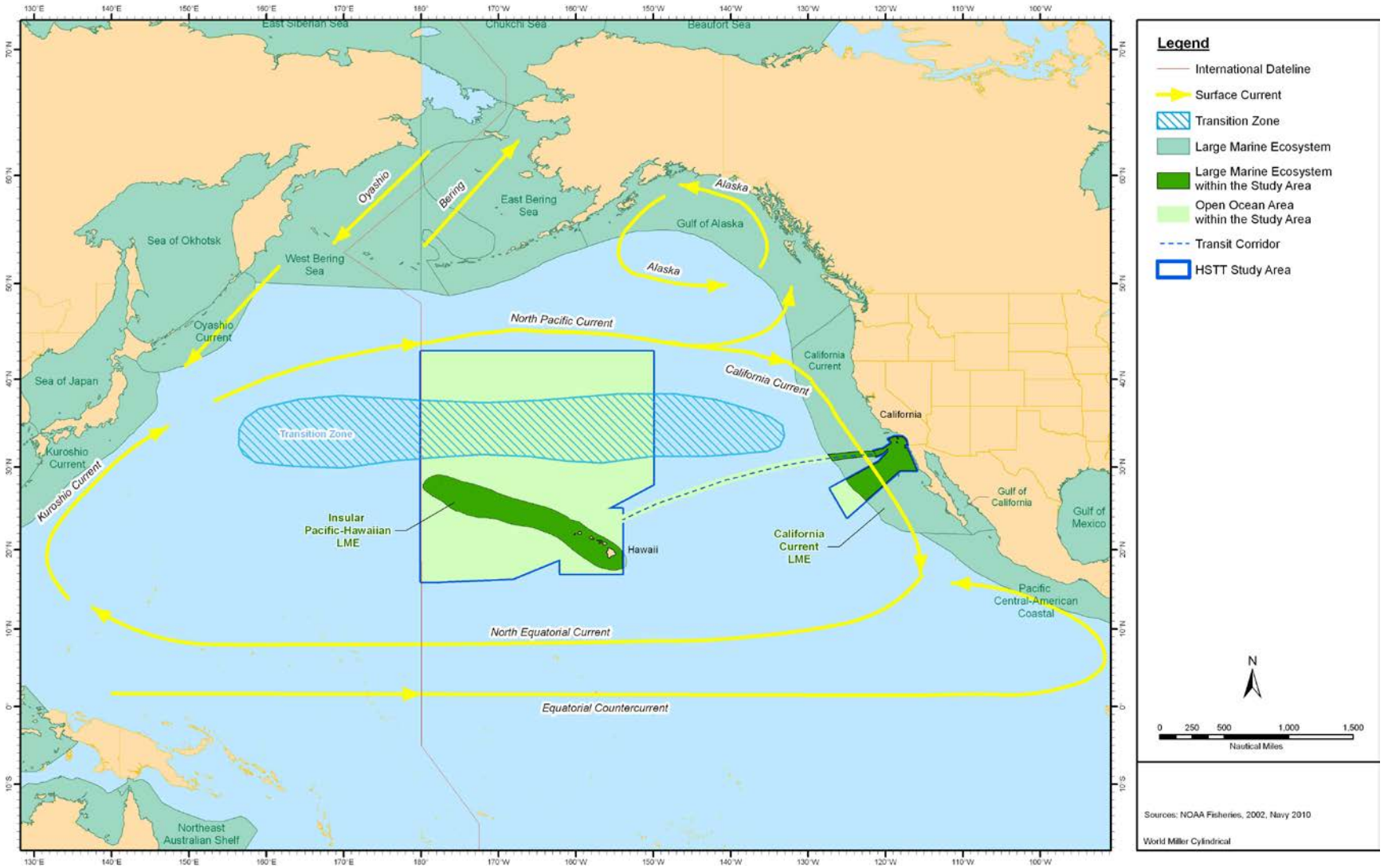


Figure 3.0-1: Large Marine Ecosystems and Open Ocean Portions of the Hawaii-Southern California Training and Testing Study Area

3.0.3.1.3 North Pacific Subtropical Gyre Open Ocean Area

North Pacific Ocean circulation is driven by the clockwise motion of the North Pacific Subtropical Gyre (Tomczak and Godfrey 2003c). 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 and Godfrey 2003c) (Figure 3.0-1). 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.

3.0.3.2 Bathymetry

This section provides a description of the bathymetry (water depth) of the Study Area. Given that the bathymetry of an area reflects the topography (surface features) of the seafloor, it is an important factor for understanding the potential impacts of Navy training and testing activities on the seafloor, the propagation of underwater sound (see Section 3.0.4.4.1, Sound Attenuation and Transmission Loss), and species diversity (see Sections 3.3–3.9). The discussion of bathymetry includes a general overview of the Study Area followed by more detailed sections by biogeographic classification area. Table 3.0-3 provides a description of the bathymetry of Navy training and testing areas within each large marine ecosystem and open ocean area.

Table 3.0-3: Summary of Bathymetric Features within Large Marine Ecosystems and Open Ocean Areas in Important Navy Training and Testing Areas

Range/Component	Description	General Bathymetry[1,2]
California Current Large Marine Ecosystem		
Range Complexes		
SOCAL Range Complex	Located offshore of Southern California and the Baja Peninsula (Mexico) in the southern half of the California Current LME.	Varying continental shelf width. Steep continental slope. Numerous near surface banks, seamounts, escarpments, canyons, and basins characterize the bathymetry of the OPAREA.
Silver Strand Training Complex	Located on the Silver Strand, a narrow, sandy isthmus separating the San Diego Bay from the Pacific Ocean.	Shallow waters of San Diego Bay to the east (see below).
Ports, Bays, and Shipyards		
Naval Base Coronado	Located on the northern end of the Silver Strand isthmus at the mouth of San Diego Bay.	Adjacent to dredged channel leading to the Bay (12 m) and shallow shoals (2 - 4 m) on either side of the channel. See San Diego Bay description below.
Naval Base San Diego	Located on the eastern shore of San Diego Bay.	
Naval Base Point Loma	Located on Point Loma, across the mouth of San Diego Bay from Naval Base Coronado.	

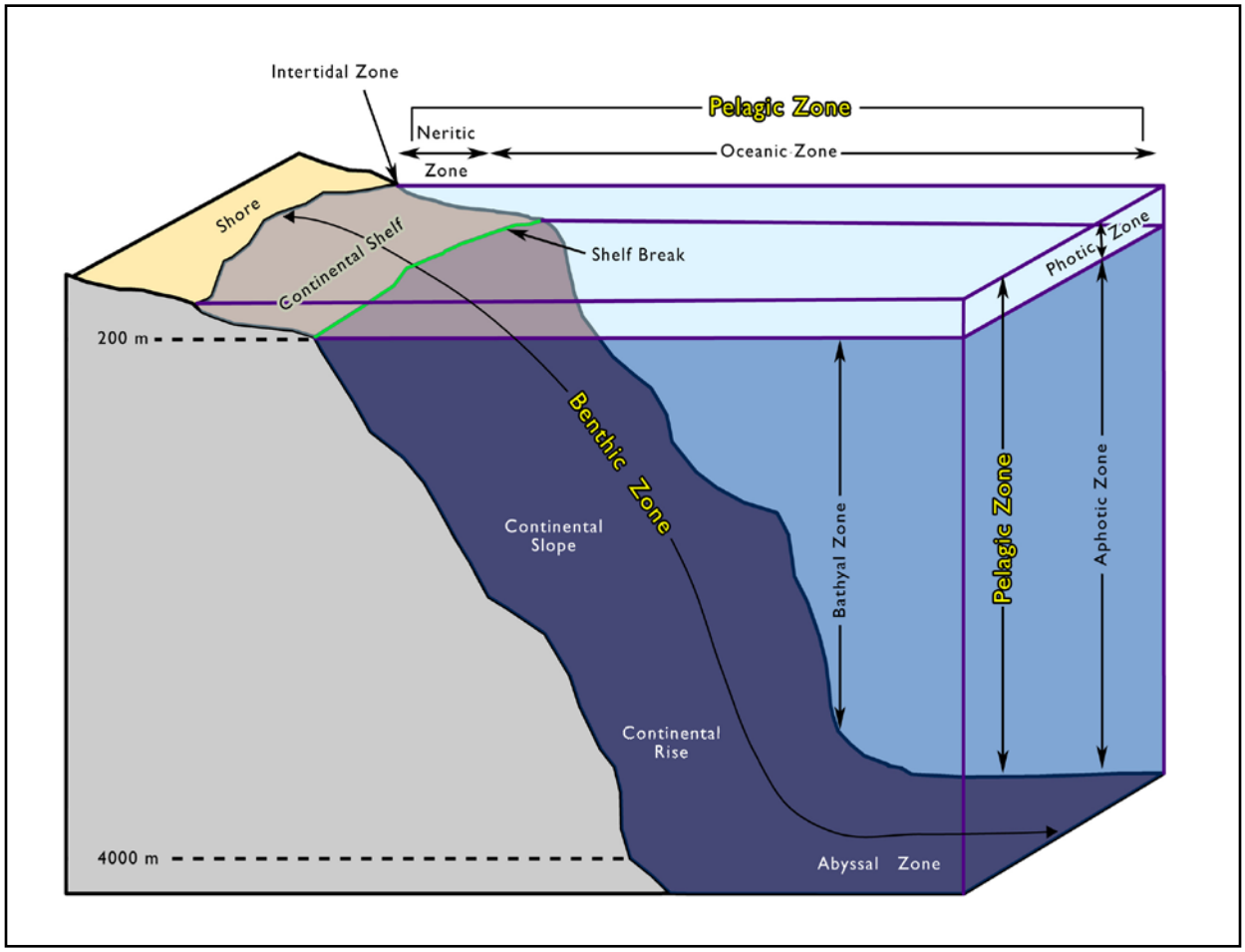
Table 3.0-3: Summary of Bathymetric Features within Large Marine Ecosystems and Open Ocean Areas in Important Navy Training and Testing Areas (continued)

Range/Component	Description	General Bathymetry[1,2]
California Current Large Marine Ecosystem (continued)		
Ocean Operating Areas Outside the Bounds of Existing Range Complexes		
Transit Corridor	Shortest route between Southern California and Hawaii linking the HRC and the SOCAL Range Complex	Open ocean with a variety of bottom types, characterized by both SOCAL Range Complex and Hawaii Range Complex features.
Bodies of Water		
San Diego Bay	Naturally formed, crescent-shaped embayment located along the Southern California coast. Approximately 25 km long and 1–4 km wide.	The mouth of the bay averages 12 m; the southern end of the bay ranges from 1–4 m deep. Shoals at 2–4 m deep are located immediately beyond the mouth of the bay on either side of the dredged approach channel.
Insular Pacific-Hawaiian Large Marine Ecosystem		
Range Complexes		
Hawaii Range Complex	Located in the central North Pacific Ocean, surrounding the Hawaiian Islands. Surface area is approximately 235,000 nm^2.	No continental shelf. Steeply sloping gradients from land to the seafloor. Atolls, seamounts, submarine plateaus are features found throughout the OPAREA.
Ports, Bases, and Shipyards		
Pearl Harbor Naval Complex	Located on the southern coast of Oahu off of Mamala Bay.	Consists of a natural estuary with a mean depth of 9.1 m. The deepest portion is along the Waipio Peninsula in the main channel with a depth of 28 m. Tidal flow is weak and variable.
Ocean Operating Areas Outside the Bounds of Existing Range Complexes		
Transit Corridor	Shortest route between Southern California and Hawaii linking the HRC and the SOCAL Range Complex.	Open ocean with a variety of bottom types, characterized by both SOCAL Range Complex and Hawaii Range Complex features.
North Pacific Subtropical Gyre Open Ocean Area		
Range Complexes		
Hawaii Range Complex	Located in the central North Pacific Ocean, surrounding the Hawaiian Islands. Surface area is approximately 235,000 nm^2.	No continental shelf. Steeply sloping gradients from land to the seafloor. Atolls, seamounts, submarine plateaus are features found throughout the OPAREA.

[1] Navy Research Laboratory 2011
[2] National Oceanic and Atmospheric Administration 2001. NOAA Nautical Charts were also reviewed to determine depth ranges at specific locations. Some "pierside activities" listed as taking place at these locations actually take place away from the coastal areas and are located inside ranges.
Notes: SOCAL = Southern California, OPAREA = Operating Area, m = meters, HRC = Hawaii Range Complex, km = kilometers, nm^2 = square nautical miles

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, which is an extension

of the continental crust. A representation of the benthic and pelagic zones of the oceans is shown in Figure 3.0-2. The continental shelf extends seaward from shore with an average gradient of just 0.1°. The distance the shelf extends seaward varies from almost non-existent to over 400 mi. (643.7 km) in the certain areas, such as the Arctic shelf of Siberia (Pickard and Emery 1990). The average width of the continental shelf is approximately 40 mi. (64.4 km), and at the termination of the shelf, referred to as the shelf break, reaches a maximum depth of approximately 660 ft. (200 m) (Tomczak and Godfrey 2003a; United Nations Educational Scientific and Cultural Organization 2009b).



Source: U.S.Department of the Navy 2007

Figure 3.0-2: Three-Dimensional Representation of the Intertidal Zone (Shoreline), Continental Margin, Abyssal Zone, and Water Column Zones

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 and Emery 1990). The continental slope extends to an average depth of approximately 9,800 ft. (2,987.04 m) and terminates at the continental rise, where the seafloor gradient decreases to approximately 0.3 degrees (Neumann and Pierson 1966). The continental rise extends from the base of the continental slope to a depth of approximately 13,000 ft. (3,962.4 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 19,600 ft. (5,974.08 m) (Pickard and Emery 1990). Abyssal zones in the Pacific Ocean reach depths greater than 26,000 ft. (7,924.8 m).

The pelagic zone describes the water column extending from the intertidal zone seaward and from the water's surface to the seafloor (Figure 3.0-2). 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 656 ft. (200.05 m) (Pickard and Emery 1990).

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

3.0.3.2.1 Bathymetry of the Hawaii Range Complex

In the open ocean areas of the Hawaii Range Complex, bathymetric features include the Hess Rise, a large plateau that occurs to the east of the Hawaii Emperor Seamount Chain, and the Shatsky Rise, a plateau that occurs to the west of the Hawaii Emperor Seamount Chain (Nemoto and Kroenke 1981) (Figure 3.0-3). The Emperor Trough and numerous fracture zones, including the Mendocino Fracture Zone, are found within this region of the North Pacific Subtropical Gyre (Nemoto and Kroenke 1981).

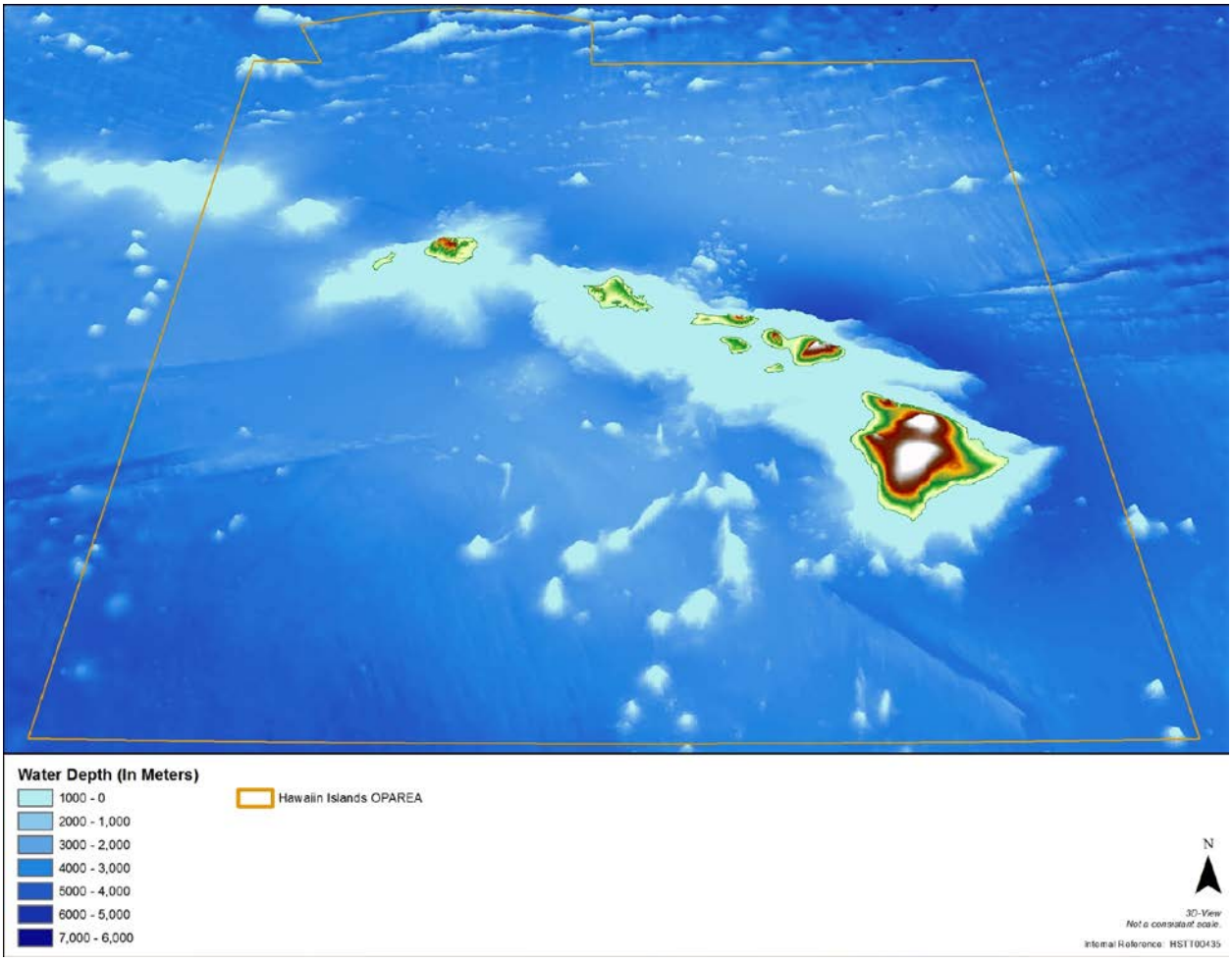


Figure 3.0-3: Bathymetry of the Hawaiian Islands

In the Insular Pacific-Hawaiian Large Marine Ecosystem, bathymetric features are dominated by the Hawaiian Archipelago. Formed from volcanic eruptions, the Hawaiian Archipelago does not have a continental shelf. The Hawaiian Archipelago is composed of high islands, reefs, banks (continental shelf underwater elevation), atolls (coral reef islands surrounding a shallow lagoon), and seamounts (deep sea floor 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 6,560 ft. (2,000 m). have been identified off of Nihoa Island and Maro Reef, off of Oahu and Molokai islands (Vetter et al. 2010) and off of Hawaii and Kauai islands.

3.0.3.2.2 Bathymetry of the Southern California Range Complex

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 3.0-4). The continental shelf off of Southern California is associated with a borderland, a broad irregular region that extends seaward of the continental shelf (Gorsline 1992; Tomczak and Godfrey 2003b; United Nations Educational Scientific and Cultural Organization 2009a). The continental shelf extends from the shore to depths of approximately 655 ft. (200 m) (Tomczak and Godfrey 2003b; United Nations Educational Scientific and Cultural Organization 2009a). The continental slope, beginning at the shelf break, descends steeply to seafloor. The continental slope is divided into the upper slope (655-2,625 ft. [200–800 m]), which is adjacent to the shelf break, the mid-slope (2,625–4,590 ft. [800-1,400 m]), and the lower slope (4,590–13,125 ft. [1,400–4,000 m]). Beyond the lower slope is a relatively flat or gently sloping abyssal plain, typically at depths between 11,480 ft. (3,500 m) and 21,325 ft. (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 and Emery 1963). This ridge drops approximately 4,900 ft. (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 the Study Area include the Coronado, La Jolla, Scripps, and Catalina.

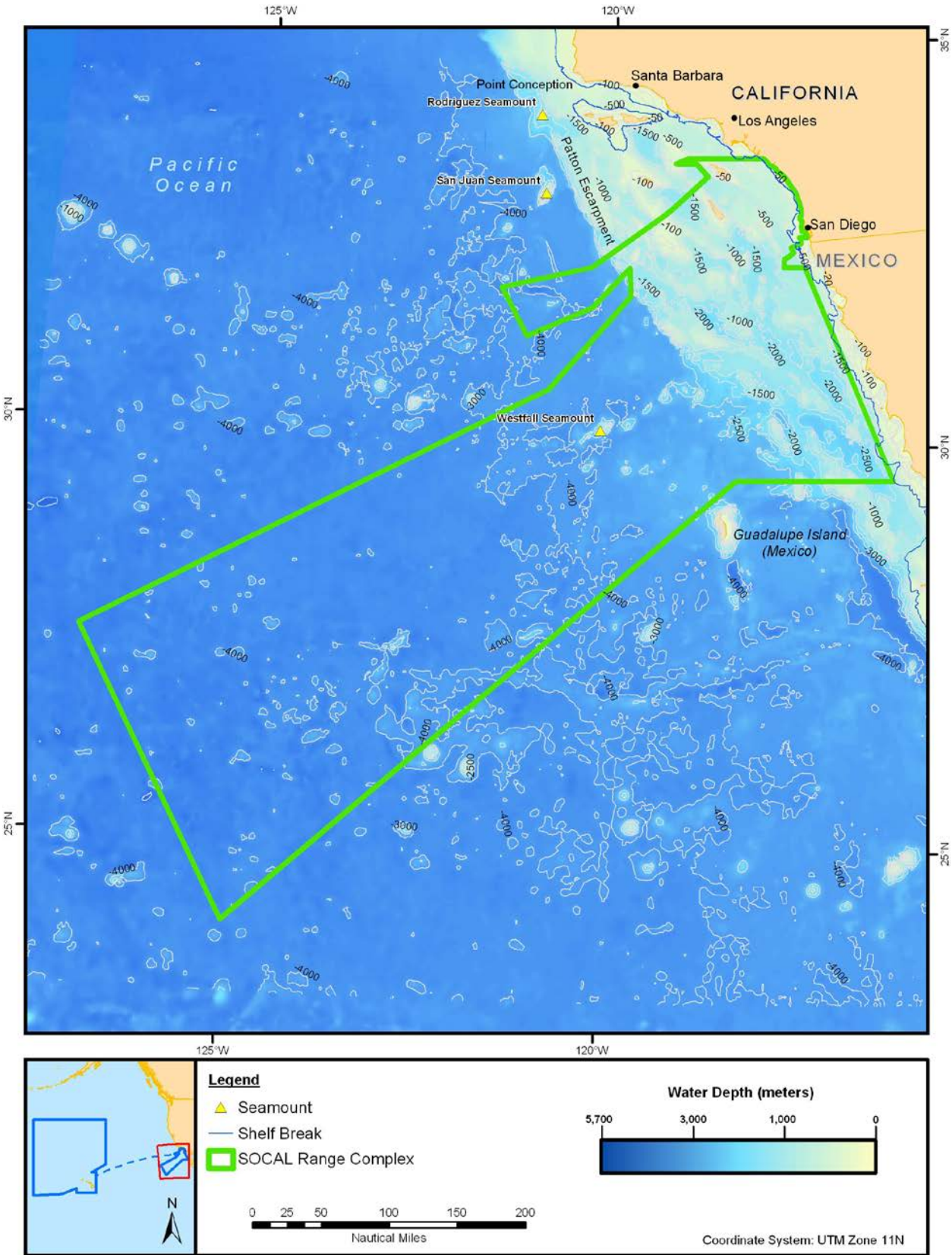


Figure 3.0-4: Bathymetry of the Southern California Range Complex

3.0.3.3 Currents, Circulation Patterns, and Water Masses

Ocean circulation in the Study Area is dominated by the clockwise motion of the North Pacific Subtropical Gyre (Tomczak and Godfrey 2003b). The North Pacific Subtropical Gyre occurs between the equator and 50° N and is bounded 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 and Godfrey 2003b).

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 330 ft. (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 California Current, California Countercurrent, and the Southern California Eddy in the SOCAL OPAREA and the North Equatorial Current, North Hawaiian Ridge Current, and Hawaii Lee Current in the Hawaii OPAREA (Figure 3.0-5 and Figure 3.0-6).

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 3 ft./s (1 m/s) (Pickard and 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 3.3 to 5.0 ft./s (1.0 to 1.5 m/s). 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 and Fujito 2010).

Thermohaline circulation—also describe as 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 at the in the North Atlantic and Southern oceans (Dickson and 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 and 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 and 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).

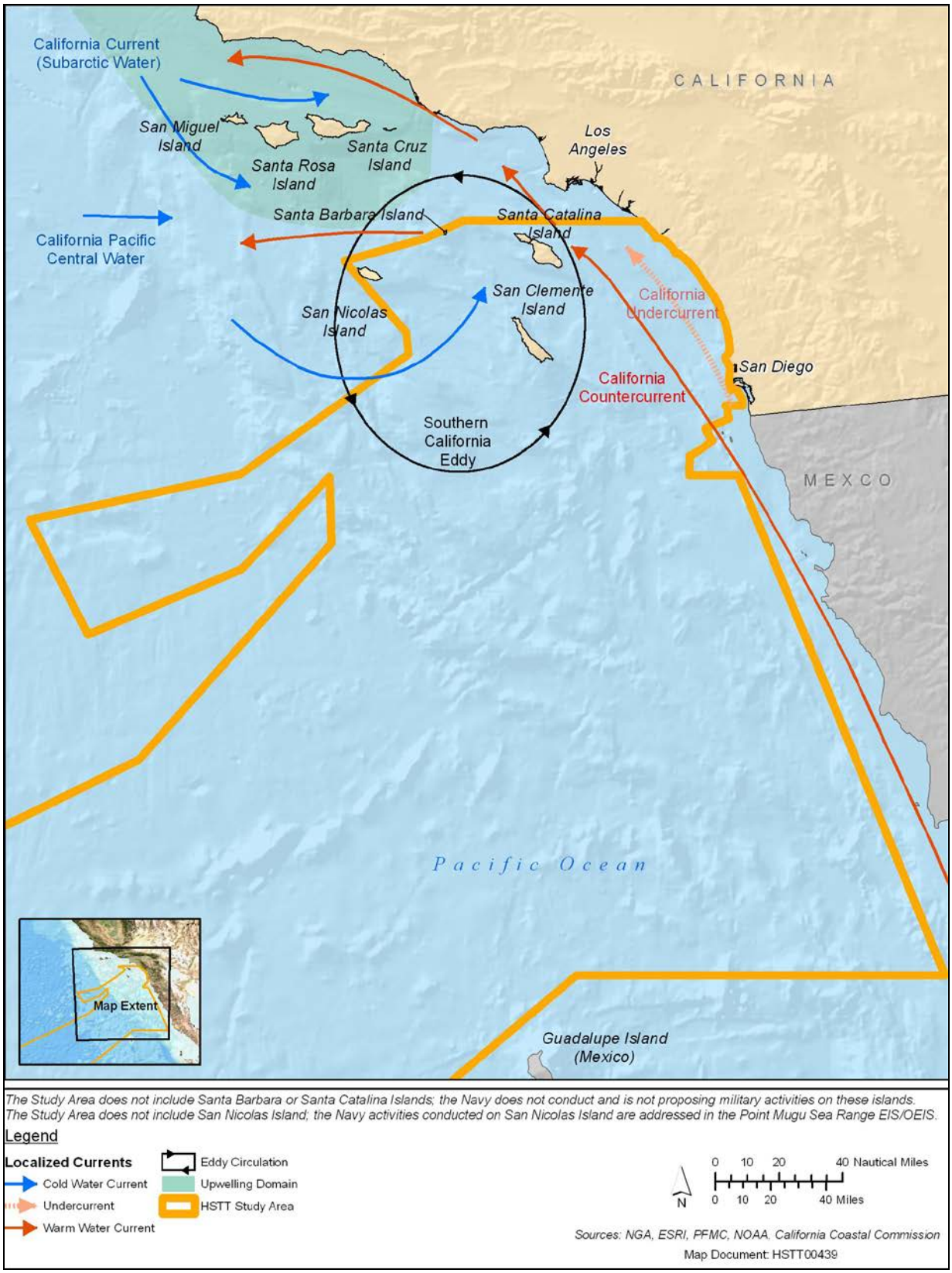


Figure 3.0-5: California Current and Countercurrent circulation in the Southern California Bight

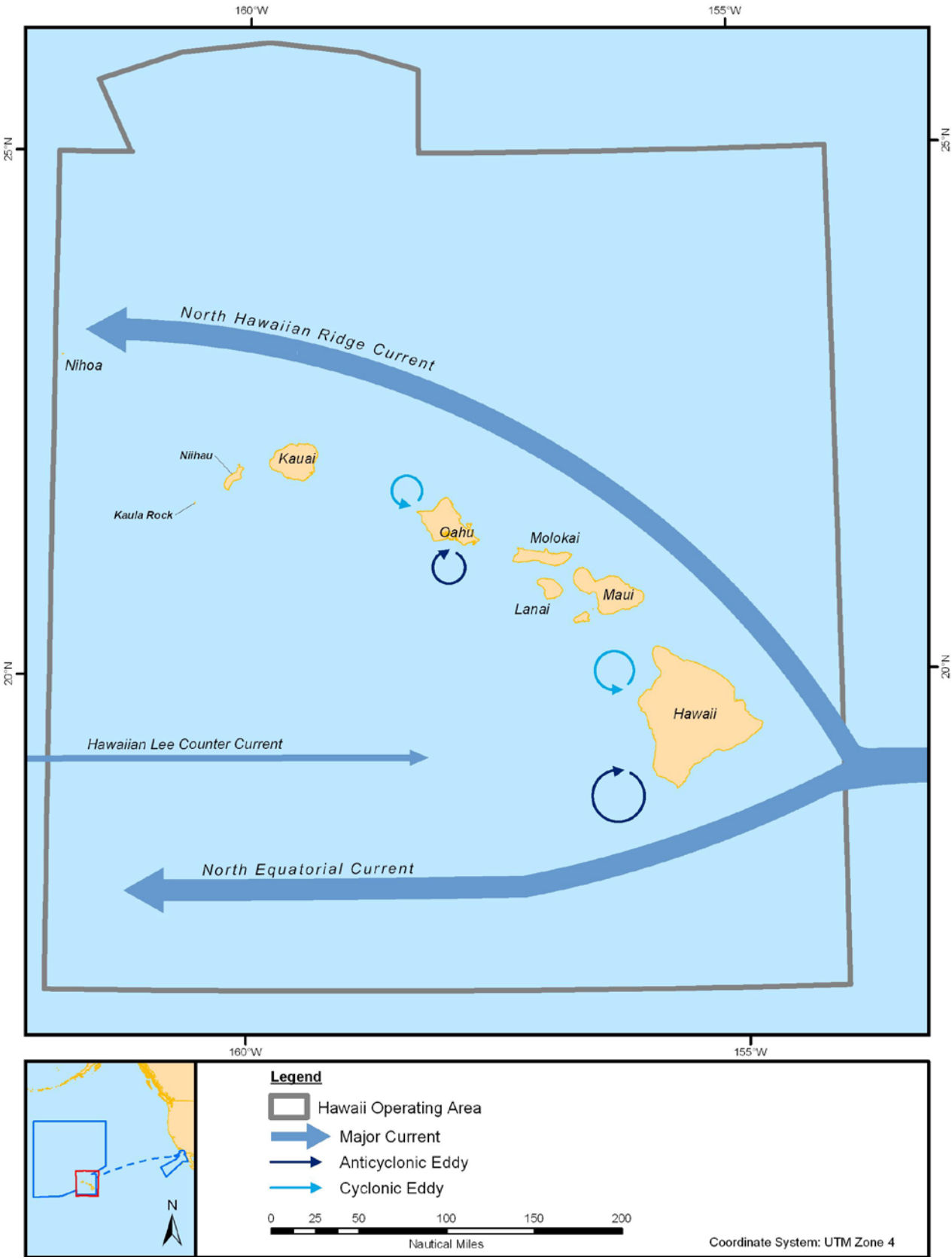


Figure 3.0-6: Surface circulation in the Hawaiian Islands

3.0.3.3.1 North Pacific Transition Zone

The North Pacific Transition Zone 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 4,970 miles (mi.) (8,000 km) across the North Pacific, the Transition Zone Chlorophyll Front shifts seasonally north and south about 620 mi. (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).

3.0.3.3.2 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 and Godfrey 2003b). 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 and 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 (see 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 1.0 ft. per second (0.3 m per second) (Tomczak and Godfrey 2003b; 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.

3.0.3.3.3 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 621 mi. (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 and Norris 2008; Tomczak and

Godfrey 2003b). The California Current flows parallel to the continental borderland along Southern California at an average current speed of 0.49 ft./s (0.15 m/s) (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 and Godfrey 2003b). 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 and 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 and 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 and Chereskin 2009). The warm, salty waters of the California Undercurrent flow at about 328 ft. (100 m) beneath the cold, nutrient rich waters of the California Current (Lynn et al. 2003) (National Research Council 1990, 1992).

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 and 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 and Bauer 2000). Photosynthesis is the production of chemical compounds into energy from sunlight. Therefore, these intrusions result in increases in phytoplankton densities and therefore enhance the rate at which organic matter is produced from the sun's energy (primary production) (Bograd 2004).

3.0.3.4 Oceanic Fronts

Similar to cold fronts and warm fronts in the atmosphere that signal an abrupt change in the weather, an oceanic front is the boundary between two water masses with distinct differences in temperature and salinity (i.e., density). An oceanic front is characterized by rapid changes in water properties over a short distance.

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 3.0-5) (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 and Niiler 1994).

3.0.3.5 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 3.0-7 and Figure 3.0-8), 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 and Godfrey 2003b). Annual average sea surface temperatures increase from north to south in the North Pacific Subtropical Gyre (Flament et al. 2009) (Figure 3.0-8).

In the Hawaii open ocean portion of the Study Area, sea surface temperature ranges from 47° Fahrenheit (F) (8° Celsius [C]) in the North Pacific Current to 86°F (30°C) in the North Pacific Subtropical Gyre (United Nations Educational Scientific and Cultural Organization 2009a) (Table 3.0-4). In the inland and open ocean Southern California portions of the Study Area, sea surface temperature ranges from approximately 54°F (12°C) in winter to 70°F (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.

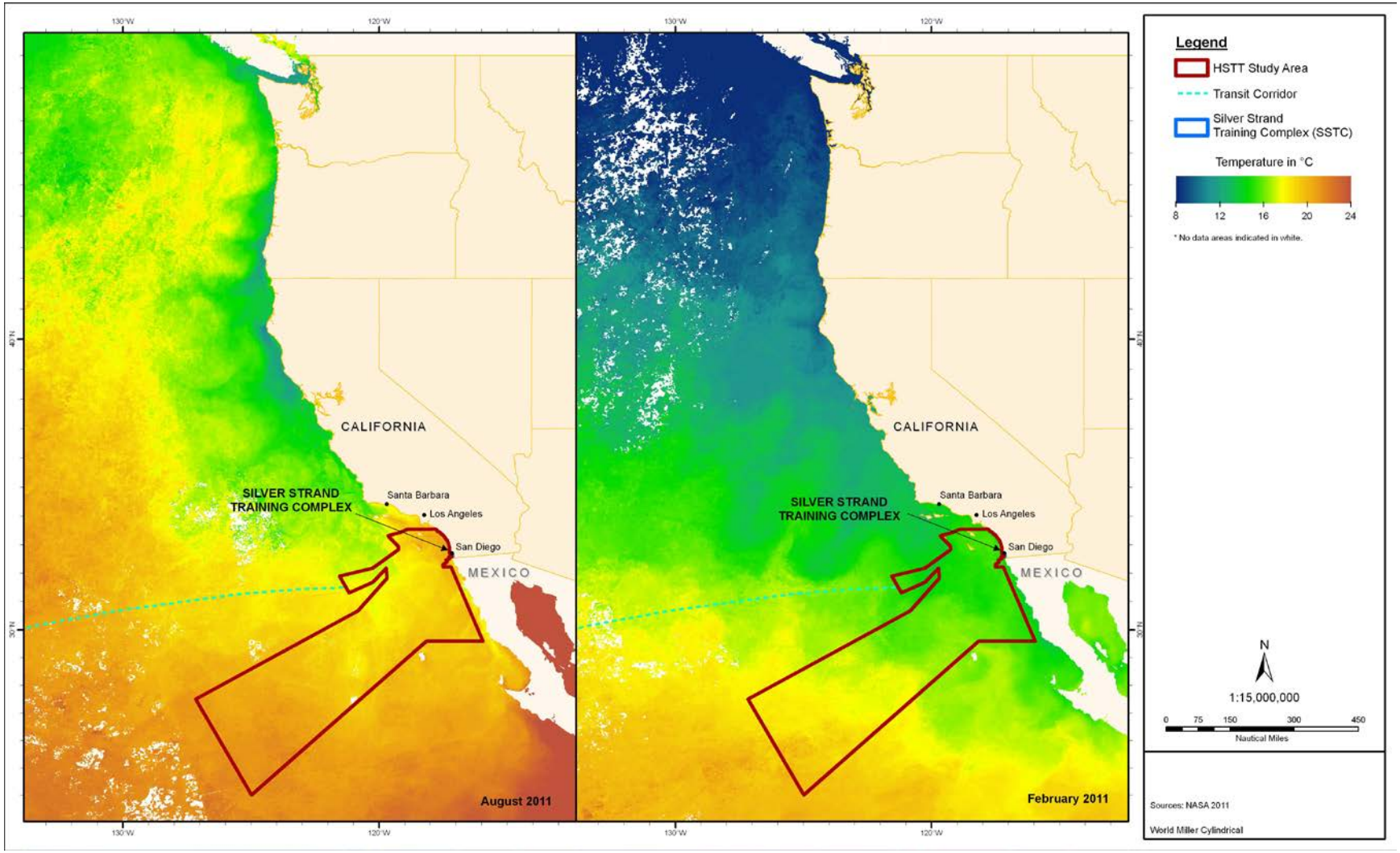
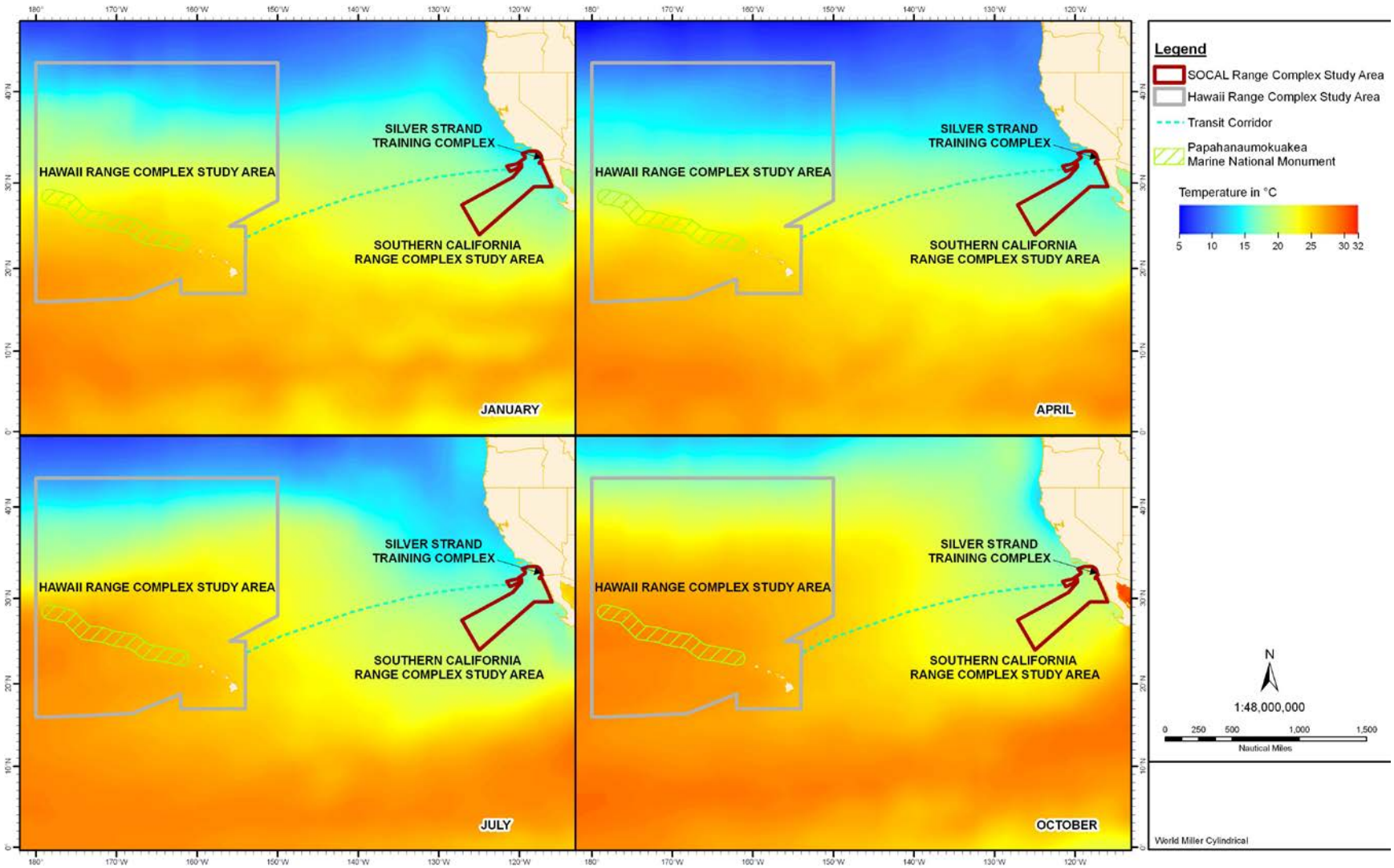


Figure 3.0-7: Sea Surface Temperature Showing the Seasonal Variation in the Convergence of the Cold California Current and Warm Equatorial Waters



Source: University of Miami Rosenstiel School of Marine and Atmospheric Science and National Oceanic and Atmospheric Administration 2007

Figure 3.0-8: Sea Surface Temperature in the Study Area

Table 3.0-4: Sea Surface Temperature Range for Large Marine Ecosystems and Open Ocean Areas of the Study Area

Region	Longitude	Latitude	Sea Surface Temperature °F (°C)
Large Marine Ecosystem			
California Current Large Marine Ecosystem	137° W–117° W	25° N–49° N	69–51 (21–11)
Insular Pacific-Hawaiian Large Marine Ecosystem	180° W–155° W	19° N–30° N	86–77 (30–25)
Open Ocean			
North Pacific Transition Zone	130° E–150° W	32° N–42° N	71–47 (22–8)
North Pacific Subtropical Gyre	130° E–150° W	6° N–37° N	85–64 (29–18)

Notes: ° = degree, F = Fahrenheit, C = Celsius, W = West, N = North, E = East

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 and 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. 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 and Hare 2002; Polovina et al. 1994). Every 20 to 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.

The Hawaii portion of the Study Area experiences El Niño events that result in decreased annual rainfall and increased sea surface temperature (Fletcher et al. 2002). The 10 driest years on record for the Hawaiian Islands are all associated with El Niño years. Coral bleaching events throughout the Hawaiian archipelago have been associated with El Niño events (Goreau and Hayes 1994). Coral bleaching is triggered by abnormally high sea surface temperatures which cause corals to lose their symbiotic (close association) algae which are what make corals colorful. Increased sea surface temperature resulting from climate change is now threatening coral reefs around the world (Spalding et al. 2007). During a La Niña event, conditions in the central Pacific can change. Typically, the trade winds strengthen, coastal upwelling and primary productivity increase, and populations of cold water fishes increase.

The Southern California portion of the Study Area experiences considerable changes during El Niño and La Niña events (Barber and Chavez 1983; Hayward 2000; Millán-Núñez et al. 1997). During an El Niño event, atmospheric temperatures increase along with corresponding increases in coastal rainfall, local sea level, sea surface temperature, the strength of the California Countercurrent, and local populations of warm water fishes. Concurrently, the trade winds weaken, upwelling and primary production decrease, and local kelp beds are severely impacted (Allen et al. 2002; Barber and Chavez 1983; Barber et al. 1985; Hayward 2000; Leet et al. 2001). During a La Niña event, opposite climactic patterns emerge. The trade winds strengthen, coastal upwelling and primary productivity increase, the California Current strengthens, and populations of cold water fishes increase. At the same time, a decrease in coastal

rainfall (drought-like conditions) and a decline in local sea level and sea surface temperatures are observed (Bograd et al. 2000).

Seawater is primarily composed of dissolved salts. Chlorine, sodium, calcium, potassium, magnesium, and sulfate make up 98 percent of the solids in seawater, with chloride and sodium making up 85 percent of that total (Garrison 1998). Sea surface salinity within the Study Area ranges from 33 to 35 parts per thousand (National Oceanic and Atmospheric Administration 2009; United Nations Educational Scientific and Cultural Organization 2009a). Within the North Pacific Subtropical Gyre and the North Pacific Current as they relate to the Hawaii portion of the Study Area, salinities decrease from north to south (Flament et al. 2009) and range from 34 to 35 parts per thousand; and in the Southern California portion of the Study Area salinities are about 33 parts per thousand (National Oceanic and Atmospheric Administration 2009).

The density of seawater varies with salinity and temperature (Libes 1992), which leads to stratification (arranged in layers). There are typically 3 density layers in the water column of the ocean: a surface layer (0–655 ft. [0–200 m]), an intermediate layer (655–4,920 ft. [200–1,500 m]), and a deep layer (below 4,920 ft. [1,500 m]) (Castro and Huber 2007).

Nutrients are chemicals or elements necessary to produce organic matter. Basic nutrients include dissolved nitrogen, phosphates, and silicates. Dissolved inorganic nitrogen occurs in ocean water as nitrates, nitrites, and ammonia, with nitrates as the dominant form. The nitrate concentration of the coastal waters within the Hawaii portion of the Study Area varies are low ranging from approximately 0.1 to 0.4 parts per billion (0.1 to 0.4 micrograms per liter) with nitrate depletion occurring during the summer months down to depths of 820 ft. (250 m) (Johnson et al. 2010). The nitrate concentration of the coastal waters within the Southern California portion of Study Area varies annually from 0.1 to 10.0 parts per billion (0.1 to 10.0 micrograms per liter). The lowest concentrations typically occur in summer. At a depth of 33 ft. (10 m), concentrations of phosphate and silicate in the California Current typically range from 0.25 to 1.25 parts per billion (0.25 to 1.25 micrograms per liter) and 2 to 15 parts per billion (2 to 15 micrograms per liter), respectively (Barber et al. 1985).

The availability of iron affects primary production in the marine environment. Iron is introduced to the marine environment primarily by rivers and wind driven transport from continents, and from volcanic eruptions (Langmann et al. 2010). Iron is a limiting factor for growth of phytoplankton in high nutrient, low chlorophyll surface water, including surface waters of the north and equatorial Pacific Ocean (Coale et al. 1998; Coale et al. 1996; Martin and Gordon 1988). Increases in iron concentrations also increases nitrogen fixation (see Section 3.0.3.6 for an explanation of nitrogen fixation) (Krishnamurthy et al. 2009).

3.0.4 Acoustic and Explosives Primer

This section introduces basic acoustic principles and terminology describing how sound travels or “propagates” in air and water. These terms and concepts are used when analyzing potential impacts due to acoustic sources and explosives used during naval training and testing. This section briefly explains the transmission of sound; introduces some of the basic mathematical formulas used to describe the transmission of sound; and defines acoustical terms, abbreviations, and units of measurement. Because seawater is a very efficient medium for the transmission of sound, the differences between transmission of sound in water and in air are discussed. Finally, it discusses the various sources of underwater sound, including physical, biological, and anthropogenic sounds.

3.0.4.1 Terminology/Glossary

Sound is an oscillation in pressure, particle displacement, or particle velocity, as well as the auditory sensation evoked by these oscillations, although not all sound waves evoke an auditory sensation (i.e., they are outside of an animal's hearing range) (American National Standards Institute 1994). Sound may be described in terms of both physical and subjective attributes. Physical attributes may be directly measured. Subjective (or sensory) attributes cannot be directly measured and require a listener to make a judgment about the sound. Physical attributes of a sound at a particular point are obtained by measuring pressure changes as sound waves pass. The following material provides a short description of some of the basic parameters of sound.

3.0.4.1.1 Particle Motion and Sound Pressure

Sound is produced when a medium (air or water in this analysis) is set into motion, often by a vibrating object within the medium. As the object vibrates, its motion is transmitted to adjacent particles of the medium. The motion of these particles is transmitted to adjacent particles, and so on. As the sound wave travels through the medium, the individual particles of the medium oscillate about their original positions but do not actually move with the sound wave. The result is a mechanical disturbance (the "sound wave") that propagates away from the source. The measurable properties of a sound are the pressure oscillations of the sound wave and the velocity, displacement amplitude, and direction of particle movements. The basic unit of sound pressure is the Pascal (Pa) (1 Pa = 1.45×10^{-4} pounds per square inch), although the most commonly encountered unit is the micro Pascal (µPa) (1 µPa = 1×10^{-6} Pa).

Animals with an eardrum or similar structure directly detect the pressure component of sound. Some marine fish also have specializations to detect pressure changes. Certain animals (e.g., most invertebrates and some marine fish) likely cannot detect sound pressure, only the particle motion component of sound. Because particle motion is most detectable near a sound source and at lower frequencies, this difference in acoustic energy sensing mechanisms limits the range at which these animals can detect most sound sources analyzed in this document.

3.0.4.1.2 Frequency

The number of oscillations or waves per second is called the frequency of the sound, and the metric is Hertz (Hz). One Hz is equal to one oscillation per second, and 1 kilohertz (kHz) is equal to 1,000 oscillations per second. The inverse of the frequency is the period or duration of one acoustic wave.

Frequency is the physical attribute most closely associated with the subjective attribute "pitch"; the higher the frequency, the higher the pitch. Human hearing generally spans the frequency range from 20 Hz to 20 kHz. The pitch based on these frequencies is subjectively "low" (at 20 Hz) or "high" (at 20 kHz).

Pure tones have a constant, single frequency. Complex tones contain multiple, discrete frequencies, rather than a single frequency. Broadband sounds are spread across many frequencies. The frequency range of a sound is called its bandwidth. A harmonic of a sound at a particular frequency is a multiple of that frequency (e.g., harmonic frequencies of a 2 kHz tone are 4 kHz, 6 kHz, 8 kHz, etc.). A source operating at a nominal frequency may emit several harmonic frequencies at much lower sound pressure levels.

In this document, sounds are generally described as either low- (less than 1 kHz), mid- (1 kHz - 10 kHz), high- (greater than 10 kHz - 100 kHz), or very high- (greater than 100 kHz and less than 200 kHz) frequency. Hearing ranges of marine animals (e.g., fish, birds, and marine mammals) are quite varied and are species-dependent. For example, some fish can hear sounds below 100 Hz and some species of marine mammals have hearing capabilities that extend above 100 kHz. Discussions of sound and potential impacts must therefore focus not only on the sound pressure, but the composite frequency of the noise and the species considered.

3.0.4.1.3 Duty Cycle

Duty cycle describes the portion of time that a sound source actually generates sound. It is defined as the percentage of the time during which a sound is generated over a total operational period. For example, if a sound navigation and ranging (sonar) source produces a 10-second ping once every 100 seconds, the duty cycle is 10 percent. Duty cycles vary among different acoustic sources; in general, a low duty cycle is 20 percent or less and a high duty cycle is 80 percent or higher.

3.0.4.1.4 Categories of Sound

3.0.4.1.4.1 Signal Versus Noise

When sound is purposely created to convey information, communicate, or obtain information about the environment, it is often referred to as a signal. Examples of sounds that could be considered signals are sonar pings, marine mammal vocalizations/echolocations, tones used in hearing experiments, and small sonobuoy explosions used for submarine detection.

Noise is undesired sound (American National Standards Institute 1994). Sounds produced by naval aircraft and vessel propulsion are considered noise because they represent possible inefficiencies and increased detectability, which are undesirable. Whether a sound is noise often depends on the receiver (i.e., the animal or system that detects the sound). For example, small explosives and sonar used to generate sounds that can locate an enemy submarine produce *signals* that are useful to sailors engaged in anti-submarine warfare, but are assumed to be *noise* when detected by marine mammals.

Noise also refers to all sound sources that may interfere with detection of a signal (background noise) and the combination of all of the sounds at a particular location (ambient noise) (American National Standards Institute 1994).

3.0.4.1.4.2 Impulsive versus Non-Impulsive Sounds

Although no standard definitions exist, sounds may be broadly categorized as impulsive or non-impulsive. Impulsive sounds feature a very rapid increase to high pressures, followed by a rapid return to the static pressure. Impulsive sounds are often produced by processes involving a rapid release of energy or mechanical impacts (Hamernik and Hsueh 1991). Explosions, airgun detonations, and impact pile driving are examples of impulsive sound sources analyzed in this document. Non-impulsive sounds lack the rapid rise time and can have longer durations than impulsive sounds. Non-impulsive sound can be continuous or intermittent. Sonar pings, vessel noise, and underwater transponders are all examples of non-impulsive sound sources analyzed in this document.

3.0.4.1.4.3 Explosive Detonations

An explosive detonation generates a high-speed shock wave that rises almost instantaneously to a maximum pressure, and then rapidly decays. At the instant of explosion, gas is instantaneously

generated at high pressure and temperature, creating a bubble. In addition, the heat causes a certain amount of water to vaporize, adding to the volume of the bubble. This action immediately begins to force the water in contact with the blast front in an outward direction creating an intense pressure wave. This shock wave passes into the surrounding medium and travels faster than the speed of sound. The near-instantaneous rise from ambient to high pressures is what makes the shock wave potentially damaging. As the high pressure wave travels away from the source, it begins to slow and act like an acoustic wave similar to other impulsive sources that lack the strong shock wave (e.g., airguns). Energy associated with the blast is also transmitted into the surrounding medium as acoustic waves.

The peak pressure experienced by a receptor (i.e., an animal) is a function of the explosive material, the net explosive weight (the equivalent explosive energy expressed in weight of trinitrotoluene [TNT]), and the distance from the charge. The peak pressure is higher for larger charge weights at a given distance and decreases for increasing distances from a given charge. In general, shock wave effects near an explosive charge increase in proportion to the cube root of the explosive weight (Young 1991). For example, shock wave impacts will double when the explosive charge weight is increased by a factor of eight (i.e., cube root of eight equals two).

If the detonation occurs underwater, and is not near the surface, gases released during the explosive chemical reaction form a bubble that pulsates as the gases expand and contract. These bubble pulsations create pressure waves that are weaker than the original shock wave but can still be damaging. If the detonation occurs at or just below the surface, a portion of the explosive power is released into the air and a pulsating gas bubble is not formed.

The detonation depth of an explosive is important because of the propagation effect known as surface-image interference. For underwater explosions near the sea surface, a distinct interference pattern arises from reflection from the water's surface. As the source depth or the source frequency decreases, these two paths increasingly, destructively interfere with each other, reaching total cancellation at the surface (barring surface reflection scattering loss). This effect can significantly reduce the peak pressures experienced near the water surface.

3.0.4.2 Sound Metrics

3.0.4.2.1 Pressure

Various sound pressure metrics are illustrated in Figure 3.0-9 for a hypothetical (a) pure tone (non-impulsive), and (b) an impulsive sound. Sound pressure varies differently with time for non-impulsive and impulsive sounds. As shown in the figure, the non-impulsive sound has a relatively gradual rise in pressure from static pressure (the ambient pressure without the added sound), while the impulsive sound has a near-instantaneous rise to a higher peak pressure. The peak pressure shown on both illustrations is the maximum absolute value of the instantaneous sound pressure during a specified time interval, which accounts for the values of peak pressures below the static pressure (American National Standards Institute 1994). Peak-to-peak pressure is the difference between the maximum and minimum sound pressures. The root-mean-squared sound pressure is often used to describe the average pressure level of sounds. As the name suggests, this method takes the square root of the average squared sound pressure values over a time interval. The duration of this time interval can have a strong effect on the measured root-mean-squared sound pressure for a given sound, especially where pressure levels vary significantly, as during an impulse. If the analysis duration includes a significant portion of the waveform after the impulse has ended and the pressure has returned to near static, the root-mean-squared level would be relatively low. If the analysis duration includes the highest pressures of the impulse and excludes the portion of the waveform after the impulse has terminated, the

root-mean-squared level would be comparatively high. For this reason, it is important to specify the duration used to calculate the root-mean-squared pressure for impulsive sounds.

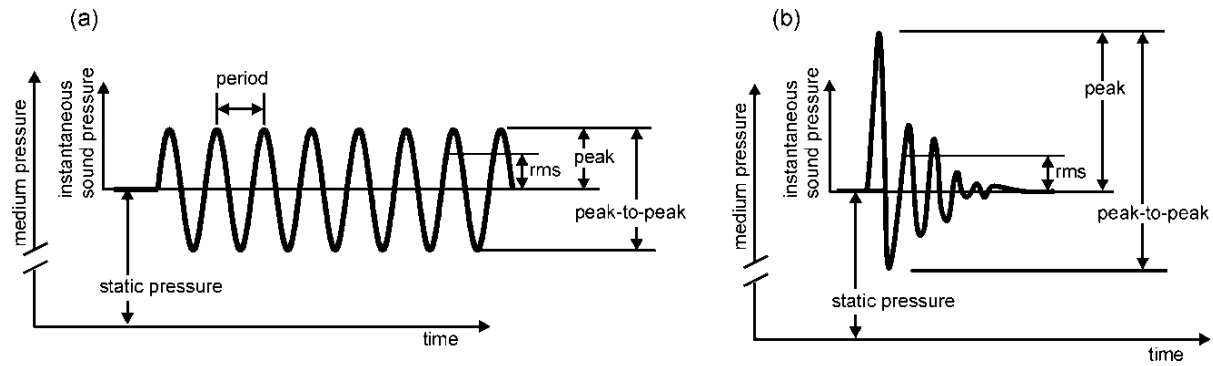


Figure 3.0-9: Various Sound Pressure Metrics for a Hypothetical (a) Pure Tone (Non-Impulsive) and (b) Impulsive Sound

3.0.4.2.1.1 Sound Pressure Level

Because mammalian ears can detect large pressure ranges and humans judge the relative loudness of sounds by the ratio of the sound pressures (a logarithmic behavior), sound pressure level is described by taking the logarithm of the ratio of the sound pressure to a reference pressure (American National Standards Institute 1994). Use of a logarithmic scale compresses the wide range of pressure values into a more usable numerical scale.

Sound levels are normally expressed in decibels (dB). To express a pressure X in decibels using a reference pressure X_{ref}, the equation is:

$$20\log_{10}\left(\frac{X}{X_{ref}}\right)$$

The pressure X is the root-mean-square value of the pressure. When a value is presented in decibels, it is important to specify the value and units of the reference pressure. Normally the decibel value is given, followed by the text "re," meaning "with reference to," and the value and unit of the reference pressure. The standard reference pressures are 1 µPa for water and 20 µPa for air (American National Standards Institute 1994). It is important to note that, because of the difference in reference units between air and water, the same absolute pressures would result in different decibel values for each medium.

3.0.4.2.1.2 Sound Exposure Level

When analyzing effects on marine animals from multiple moderate-level sounds, it is necessary to have a metric that quantifies cumulative exposure(s) (American National Standards Institute 1994). The sound exposure level can be thought of as a composite metric that represents both the intensity of a sound and its duration. Individual time-varying noise events (e.g., a series of sonar pings) have two main characteristics: (1) a sound level that changes throughout the event and (2) a period of time during which the source is exposed to the sound. Cumulative sound exposure level provides a measure of the net impact of the entire acoustic event, but it does not directly represent the sound level heard at any

given time. Sound exposure level is determined by calculating the decibel level of the cumulative sum-of-squared pressures over the duration of a sound, with units of dB re 1 micro Pascal-squared seconds (μPa^2-s) for sounds in water.

Some rules of thumb for sound exposure level are as follows:

- The numeric value of sound exposure level is equal to the sound pressure level of a one-second sound that has the same total energy as the exposure event. If the sound duration is one second, sound pressure level and sound exposure level have the same numeric value (but not the same reference quantities). For example, a one-second sound with a sound pressure level of 100 dB re 1 µPa has a sound exposure level of 100 dB re 1 squared micro Pascal-second (μPa^2-s).
- If the sound duration is constant but the sound pressure level changes, sound exposure level will change by the same number of decibels as the sound pressure level.
- If the sound pressure level is held constant and the duration (*T*) changes, sound exposure level will change as a function of $10\log_{10}(T)$:
    - $10\log_{10}(10) = 10$, so increasing duration by a factor of 10 raises sound exposure level by 10 dB.
    - $10\log_{10}(0.1) = -10$, so decreasing duration by a factor of 10 lowers sound exposure level by 10 dB.
    - Since $10\log_{10}(2) \approx 3$, so doubling the duration increases sound exposure level by 3 dB.
    - $10\log_{10}(1/2) \approx -3$, so halving the duration lowers sound exposure level by 3 dB.

Figure 3.0-10 illustrates the summation of energy for a succession of sonar pings. In this hypothetical case, each ping has the same duration and sound pressure level. The sound exposure level at a particular location from each individual ping is 100 dB re 1 μPa^2-s (red circles). The upper, blue curve shows the running total or cumulative sound exposure level.

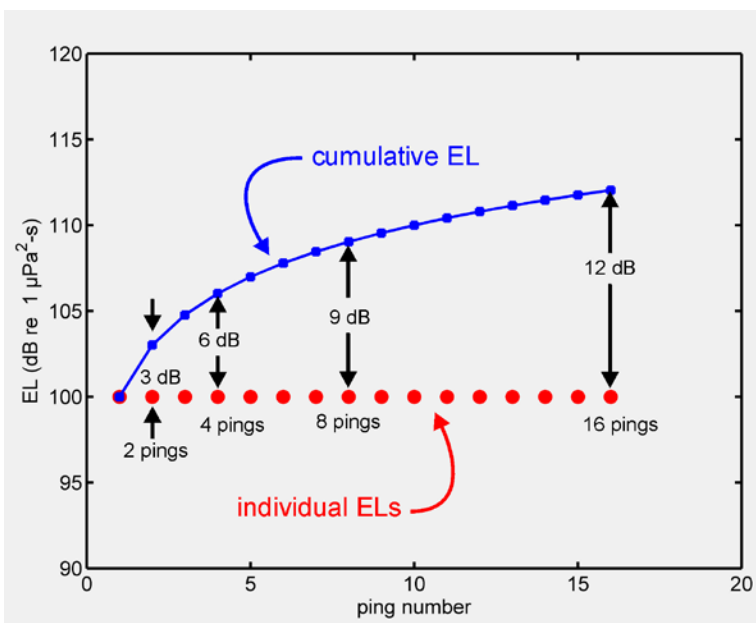


Figure 3.0-10: Summation of Acoustic Energy (Cumulative Exposure Level, or Sound Exposure Level) from a Hypothetical, Intermittently Pinging, Stationary Sound Source (EL = Exposure Level)

After the first ping, the cumulative sound exposure level is 100 dB re 1 μPa^2-s. Since each ping has the same duration and sound pressure level, receiving two pings is the same as receiving a single ping with twice the duration. The cumulative sound exposure level from two pings is therefore 103 dB re 1 μPa^2-s. The cumulative sound exposure level from four pings is 3 dB higher than the cumulative sound exposure level from two pings, or 106 dB re 1 μPa^2-s. Each doubling of the number of pings increases the cumulative sound exposure level by 3 dB.

Figure 3.0-11 shows a more realistic example where the individual pings do not have the same sound pressure level or sound exposure level. These data were recorded from a stationary hydrophone as a sound source approached, passed, and moved away from the hydrophone. As the source approached the hydrophone, the received sound pressure level from each ping increased, causing the sound exposure level of each ping to increase. After the source passed the hydrophone, the received sound pressure level and sound exposure level from each ping decreased as the source moved farther away (downward trend of red line), although the cumulative sound exposure level increased with each additional ping received (slight upward trend of blue line). The main contributions are from those pings with the highest individual sound exposure levels. Individual pings with sound exposure levels 10 dB or more below the ping with the highest level contribute little (less than 0.5 dB) to the total cumulative sound exposure level. This is shown in Figure 3.0-11 where only a small error is introduced by summing the energy from the eight individual pings with sound exposure level greater than 185 dB re 1 μPa^2-s (black line), as opposed to including all pings (blue line).

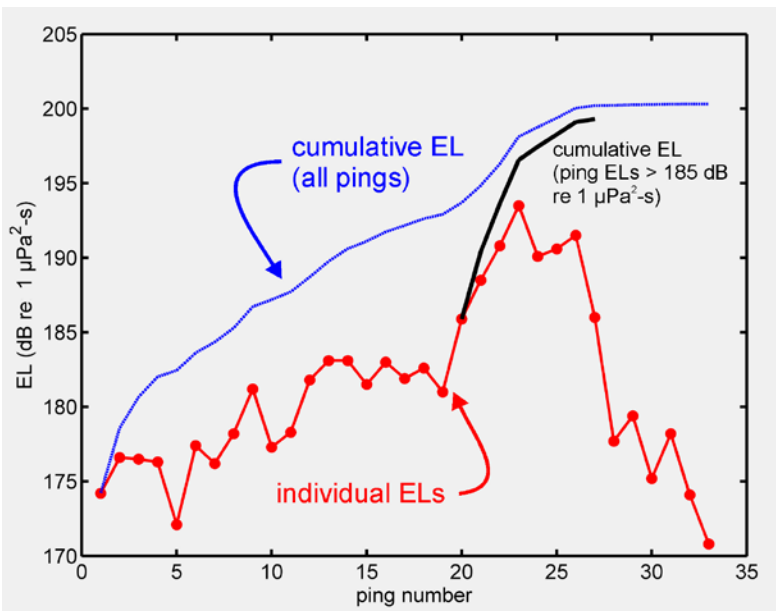


Figure 3.0-11: Cumulative Sound Exposure Level under Realistic Conditions with a Moving, Intermittently Pinging Sound Source (Cumulative Exposure Level = Sound Exposure Level)

3.0.4.2.1.3 Impulse (Pa-s)

Impulse is a metric used to describe the pressure and time component of an intense shock wave from an explosive source. The impulse calculation takes into account the magnitude and duration of the initial peak positive pressure, which is the portion of an impulsive sound most likely to be associated with damage. Specifically, impulse is the time integral of the initial peak positive pressure with units Pascal-seconds (Pa-s). The peak positive pressure for an impulsive sound is shown in Figure 3.0-9 as the

first and largest pressure peak above static pressure. This metric is used to assess potential injurious effects from explosives.

3.0.4.3 Loudness and Auditory Weighting Functions

Animals, including humans, are not equally sensitive to sounds across their entire hearing range. The subjective judgment of a sound level by a receiver such as an animal is known as loudness. Two sounds received at the same sound pressure level (an objective measurement), but at two different frequencies, may be perceived by an animal at two different loudness levels depending on its hearing sensitivity (lowest sound pressure level at which a sound is first audible) at the two different frequencies. Furthermore, two different species may judge the relative loudness of the two sounds differently.

Auditory weighting functions are a method common in human hearing risk analysis to account for differences in hearing sensitivity at various frequencies. This concept can be applied to other species as well. When used in analyzing the impacts of sound on an animal, auditory weighting functions adjust received sound levels to emphasize ranges of best hearing and de-emphasize ranges of less or no sensitivity. A-weighted sound levels, often seen in units of "dBA," (A-weighted decibels) are frequency-weighted to account for the sensitivity of the human ear to a barely audible sound. Many measurements of sound in air appear as A-weighted decibels in the literature because the intent of the authors is often to assess noise impacts on humans.

3.0.4.4 Predicting How Sound Travels

Sounds are produced throughout a wide range of frequencies, including frequencies beyond the audible range of a given receptor. Most sounds heard in the environment do not consist of a single frequency, but rather a broad band of frequencies differing in sound level. The intensities of each frequency add to generate perceptible sound.

The speed of sound is not affected by its intensity, amplitude, or frequency, but rather depends wholly on characteristics of the medium through which it is passing. Sound generally travels faster as the density of the medium increases. Speeds of sound through air are primarily influenced by air temperature, relative humidity, and pressure, averaging about 1,115 ft./s (340 m/s) at standard barometric pressure. Sound speeds in air increase as air temperature increases. Sound travels differently in the water than in air because seawater is a very efficient medium for the transmission of sound. Sound moves at a faster speed in water, about 4,921 ft./s (1,500 m/s). The speed of sound through water is influenced by temperature, pressure, and salinity because sound travels faster as any of these parameters increase.

In the simple case of sound propagating from a point source without obstruction or reflection, the sound waves take on the shape of an expanding sphere. As spherical propagation continues, the sound energy is distributed over an ever-larger area following the inverse square law: the intensity of a sound wave decreases inversely with the square of the distance between the source and the receptor. For example, doubling the distance between the receptor and a sound source results in a reduction in the intensity of the sound of one-fourth of its initial value; tripling the distance results in one-ninth of the original intensity, and so on (Figure 3.0-12). As expected, sound intensity drops at increasing distance from the point source. In spherical propagation, sound pressure levels drop an average of 6 dB for every doubling of distance from the source. Potential impacts on sensitive receptors, then, are directly related to the distance from the receptor to the noise source, and the intensity of the noise source itself.

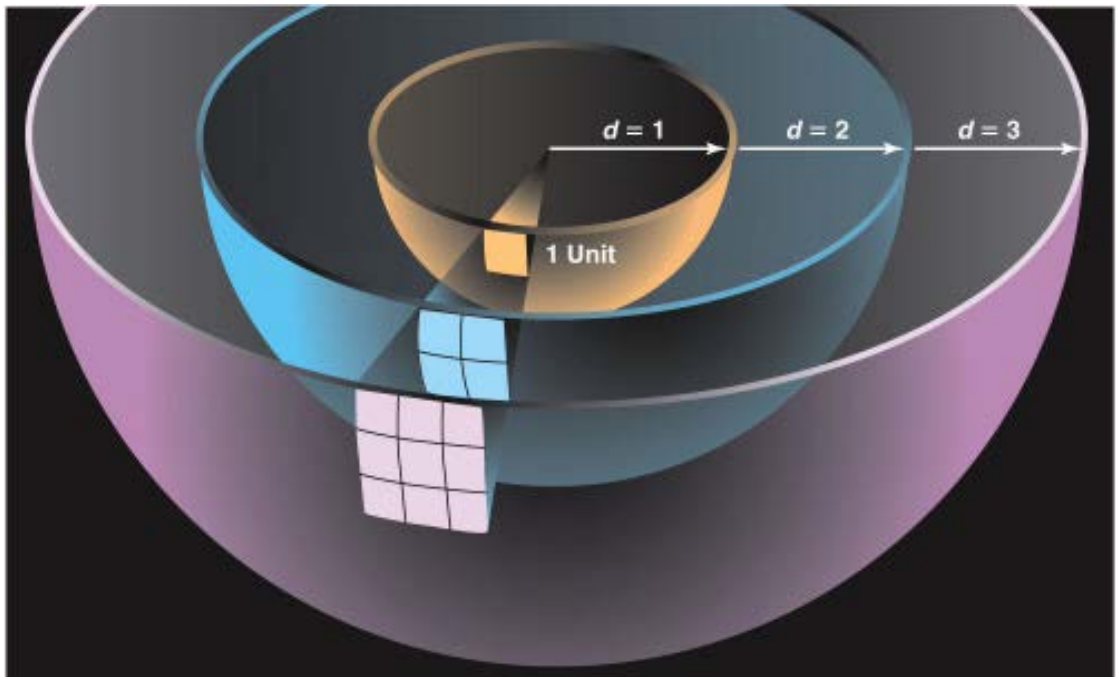


Figure 3.0-12: Graphical Representation of the Inverse-Square Relationship in Spherical Spreading

While the concept of a sound wave traveling from its source to a receptor is relatively simple, sound propagation is quite complex because of the simultaneous presence of numerous sound waves of different frequencies and other phenomena such as reflections of sound waves and subsequent constructive (additive) or destructive (cancelling) interferences between reflected and incident waves. Other factors such as refraction, diffraction, bottom types, and surface conditions also affect sound propagation. While simple examples are provided here for illustration, the Navy Acoustic Effects Model used to quantify acoustic exposures to marine mammals and sea turtles takes into account the influence of multiple factors to predict acoustic propagation (Marine Species Modeling Team 2012).

3.0.4.4.1 Sound Attenuation and Transmission Loss

As a sound wave passes through a medium, the intensity decreases with distance from the sound source. This phenomenon is known as attenuation or propagation loss. Sound attenuation may be described in terms of transmission loss (TL). The units of transmission loss are dB. The transmission loss is used to relate the source level (SL), defined as the sound pressure level produced by a sound source at a distance of 1 m, and the received level (RL) at a particular location, as follows:

$$RL = SL - TL$$

The main contributors to sound attenuation are as follows:

- Geometrical spreading of the sound wave as it propagates away from the source
- Sound absorption (conversion of sound energy into heat)
- Scattering, diffraction, multipath interference, boundary effects
- Other nongeometrical effects (Urick 1983)

3.0.4.4.1.1 Spreading Loss

Spreading loss or divergence loss is a geometrical effect representing regular weakening of a sound wave as it spreads out from a source (Campbell et al. 1988). Spreading describes the reduction in sound pressure caused by the increase in surface area as the distance from a sound source increases. Spherical and cylindrical spreading are common types of spreading loss.

As described before, a point sound source in a homogeneous medium without boundaries will radiate spherical waves—the acoustic energy spreads out from the source in the form of a spherical shell. As the distance from the source increases, the shell surface area increases. If the sound power is fixed, the sound intensity must decrease with distance from the source (intensity is power per unit area). The surface area of a sphere is $4\pi r^2$, where r is the sphere radius, so the change in intensity is proportional to the radius squared. This relationship is known as the spherical spreading law. The transmission loss for spherical spreading is:

$$TL = 20\log_{10} r$$

where *r* is the distance from the source. This is equivalent to a 6 dB reduction in sound pressure level for each doubling of distance from the sound source. For example, calculated transmission loss for spherical spreading is 40 dB at 100 m and 46 dB at 200 m.

In cylindrical spreading, spherical waves expanding from the source are constrained by the water surface and the seafloor and take on a cylindrical shape. In this case the sound wave expands in the shape of a cylinder rather than a sphere and the transmission loss is:

$$TL = 10\log_{10} r$$

Cylindrical spreading is an approximation to wave propagation in a water-filled channel with horizontal dimensions much larger than the depth. Cylindrical spreading predicts a 3 dB reduction in sound pressure level for each doubling of distance from the source. For example, calculated transmission loss for cylindrical spreading is 20 dB at 100 m and 23 dB at 200 m.

3.0.4.4.1.2 Reflection and Refraction

When a sound wave propagating in a medium encounters a second medium with a different density or sound speed (e.g., the air-water boundary) part of the incident sound will be reflected back into the first medium and part will be transmitted into the second medium (Kinsler et al. 1982). If the second medium has a different sound speed than the first, the propagation direction will change as the sound wave enters the second medium; this phenomenon is called refraction. Refraction may also occur within a single medium if the sound speed varies in the medium.

Refraction of sound resulting from spatial variations in the sound speed is one of the most important phenomena that affects sound propagation in water (Urick 1983). The sound speed in the ocean primarily depends on hydrostatic pressure (i.e., depth) and temperature. Sound speed increases with both hydrostatic pressure and temperature. In seawater, temperature has the most important effect on sound speed for depths less than about 300 m. Below 1,500 m, the hydrostatic pressure is the dominant factor because the water temperature is relatively constant. The variation of sound speed with depth in the ocean is called a sound speed profile.

Although the actual variations in sound speed are small, the existence of sound speed gradients in the ocean has an enormous effect on the propagation of sound in the deep ocean. If one pictures sound as rays emanating from an underwater source, the propagation of these rays changes as a function of the sound speed profile in the water column. Specifically, the directions of the rays bend toward regions of slower sound speed. This phenomenon creates ducts in which sound becomes "trapped," allowing it to propagate with high efficiency for large distances within certain depth boundaries. During winter months, the reduced sound speed at the surface due to cooling can create a surface duct that efficiently propagates sound such as shipping noise. The deep sound channel or Sound Frequency and Ranging channel is another duct that exists where sound speeds are lowest in the water column (600 m–1,200 m depth at the mid-latitudes). Intense low-frequency underwater sounds, such as explosions, can be detected halfway around the world from their source via the Sound Frequency and Ranging channel (Baggeroer and Munk 1992).

3.0.4.4.1.3 Diffraction, Scattering, and Reverberation

Sound waves experience diffraction in much the same manner as light waves. Diffraction may be thought of as the bending of a sound wave around an obstacle. Common examples include sound heard from a source around the corner of a building and sound propagating through a small gap in an otherwise closed door or window. An obstacle or inhomogeneity (e.g., smoke, suspended particles, or gas bubbles) in the path of a sound wave causes scattering if secondary sound spreads out from it in a variety of directions (Pierce 1989). Scattering is similar to diffraction. Normally diffraction is used to describe sound bending or scattering from a single object, and scattering is used when there are multiple objects. Reverberation, or echo, refers to the prolongation of a sound that occurs when sound waves in an enclosed space are repeatedly reflected from the boundaries defining the space, even after the source has stopped emitting.

3.0.4.4.1.4 Multipath Propagation

In multipath propagation, sound may not only travel a direct path from a source to a receiver, but also be reflected from the surface or bottom multiple times before reaching the receiver (Urick 1983). At some distances, the reflected wave will be in phase with the direct wave (their waveforms add together) and at other distances the two waves will be out of phase (their waveforms cancel). The existence of multiple sound paths, or rays, arriving at a single point can result in multipath interference, a condition that permits the addition and cancellation between sound waves resulting in the fluctuation of sound levels over short distances. A special case of multipath propagation loss is called the Lloyd mirror effect, where the sound field near the water's surface reaches a minimum because of the destructive interference (cancellation) between the direct sound wave and the sound wave being reflected from the surface. This can cause the sound level to decrease dramatically within the top few meters of the water column.

3.0.4.4.1.5 Surface and Bottom Effects

Because the sea surface reflects and scatters sound, it has a major effect on the propagation of underwater sound in applications where either the source or receiver is at a shallow depth (Urick 1983). If the sea surface is smooth, the reflected sound pressure is nearly equal to the incident sound pressure; however, if the sea surface is rough, the amplitude of the reflected sound wave will be reduced.

The sea bottom is also a reflecting and scattering surface, similar to the sea surface. Sound interaction with the sea bottom is more complex, however, primarily because the acoustic properties of the sea bottom are more variable and the bottom is often layered into regions of differing density and sound

speed. The Lloyd mirror effect may also be observed from sound sources located near the sea bottom. For a hard bottom such as rock, the reflected wave will be approximately in phase with the incident wave. Thus, near the ocean bottom, the incident and reflected sound pressures may add together, resulting in an increased sound pressure near the sea bottom.

3.0.4.4.2 Air-Water Interface

Sound from aerial sources such as aircraft, muzzle blasts, and projectile sonic booms, can be transmitted into the water. The most studied of these sources are fixed-wing aircraft and helicopters, which create noise with most energy below 500 Hz. Noise levels in water are highest at the surface and are highly dependent on the altitude of the aircraft and the angle at which the aerial sound encounters the ocean surface. Transmission of the sound once it is in the water is identical to any other sound as described in the section above.

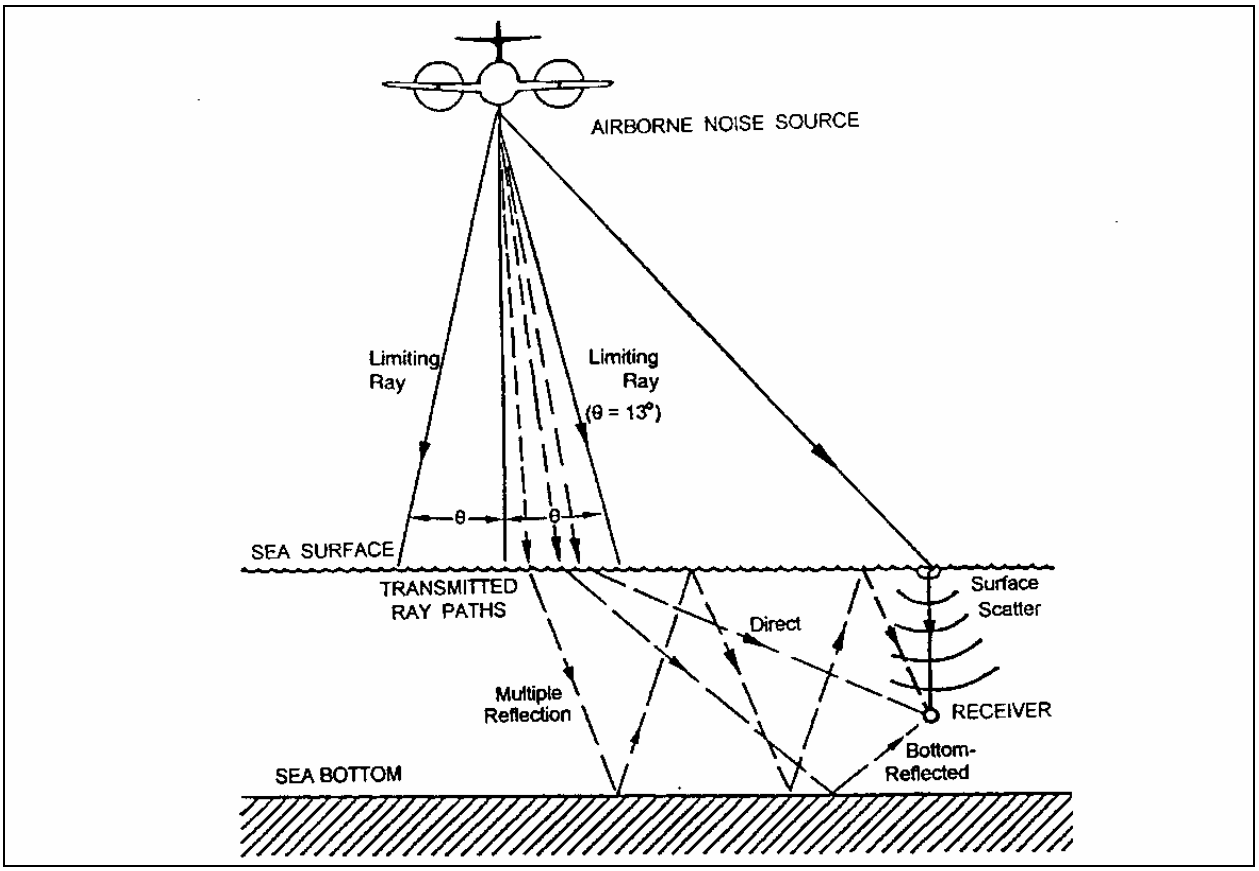
Transmission of sound from a moving airborne source to a receptor underwater is influenced by numerous factors and has been addressed by Urick (1983), Young (1973), Richardson et al. (1995), Eller and Cavanagh (2000), Laney and Cavanagh (2000), and others. Sound is transmitted from an airborne source to a receptor underwater by four principal means: (1) a direct path, refracted upon passing through the air-water interface; (2) direct-refracted paths reflected from the bottom in shallow water; (3) evanescent transmission in which sound travels laterally close to the water surface; and (4) scattering from interface roughness due to wave motion.

Airborne sound is refracted upon transmission into water because sound waves move faster through water than through air (a ratio of about 0.23:1). Based on this difference, the direct sound path is reflected if the sound reaches the surface at an angle more than 13 degrees from vertical. As a result, most of the acoustic energy transmitted into the water from an aircraft arrives through a relatively narrow cone extending vertically downward from the aircraft (Figure 3.0-13). The intersection of this cone with the surface traces a “footprint” directly beneath the flight path, with the width of the footprint being a function of aircraft altitude. Sound may enter the water outside of this cone due to surface scattering and as evanescent waves, which travel laterally near the water surface.

The sound pressure field is actually doubled (+6 dB) at the air-to-water interface because of the large difference in the acoustic properties of water and air. For example, an airborne sound with a sound pressure level of 100 dB re 1 µPa at the sea surface becomes 106 dB re 1 µPa just below the surface. The pressure and sound levels then decrease with increasing distance as they would for any other in-water noise.

3.0.4.4.3 Sonic Booms

A sonic boom occurs when an object, such as an aircraft or projectile, exceeds the speed of sound (referred to as supersonic flight). When an object exceeds the speed of sound, air molecules are pushed aside with great force, forming a shock front much like a boat creates a bow wave. All supersonic aircraft generate two shock fronts. One is immediately in front of the aircraft; the other is immediately behind it. These shock fronts “push” a sharply defined surge in air pressure in front of them, creating a sonic boom consisting of two very closely spaced impulses. The two impulses are usually heard as a single sonic boom.



Source: Richardson et al. 1995

Figure 3.0-13: Characteristics of Sound Transmission through the Air-Water Interface

Sonic booms differ from most other sounds because they are impulsive, there is no warning of their impending occurrence, and the peak levels of a sonic boom are higher than those for most other types of airborne noise. Although objects exceeding the speed of sound always create a sonic boom, not all sonic booms are heard near the water or ground surface. As altitude increases, air temperature normally decreases, and these layers of temperature change cause the shock front to be turned upward as it travels toward the ground. Depending on the altitude of the aircraft and its speed, the shock fronts of many sonic booms are bent upward sufficiently that they never reach the ground. This same phenomenon also acts to limit the width (area covered) of those sonic booms that actually do reach the ground.

3.0.4.5 Ambient Noise

Ambient noise is the collection of ever-present sounds of both natural and human-generated origin. Ambient noise in the ocean comprises sound generated by natural physical, natural biological, and anthropogenic (human-generated) sources (Figure 3.0-14). Preindustrial physical and biological noise sources in marine environments were often not high enough to interfere with the hearing of marine animals (Richardson et al. 1995). However, the increase in anthropogenic noise sources in recent times is a concern.

Except for some sounds generated by marine mammals, most natural ocean sound is broadband (composed of a spectrum of numerous frequencies). As shown in Figure 3.0-14, virtually the entire frequency spectrum is represented in ambient sound sources (National Research Council 2003, adapted

from Wenz 1962). Earthquakes and explosions produce sound signals from 1 Hz to 100 Hz; marine species can produce signals from 100 Hz to more than 10,000 Hz; and commercial shipping, industrial activities, and naval ships have signals between 10 Hz and 10,000 Hz (Figure 3.0-14). Spray and bubbles associated with breaking waves are the major contributors to the ambient sound in the 500 Hz to 100,000 Hz range. At frequencies greater than 100,000 Hz, "thermal noise" caused by the random motion of water molecules is the primary source. Ambient sources, especially from wave and tidal action, can cause coastal environments to have particularly high ambient sound levels.

3.0.4.6 Underwater Sounds

Physical, biological, and anthropogenic sounds all contribute to the ambient underwater noise environment. Example source levels for various underwater sounds are shown in Table 3.0-5. Many naturally occurring sounds have source levels similar to anthropogenic sounds.

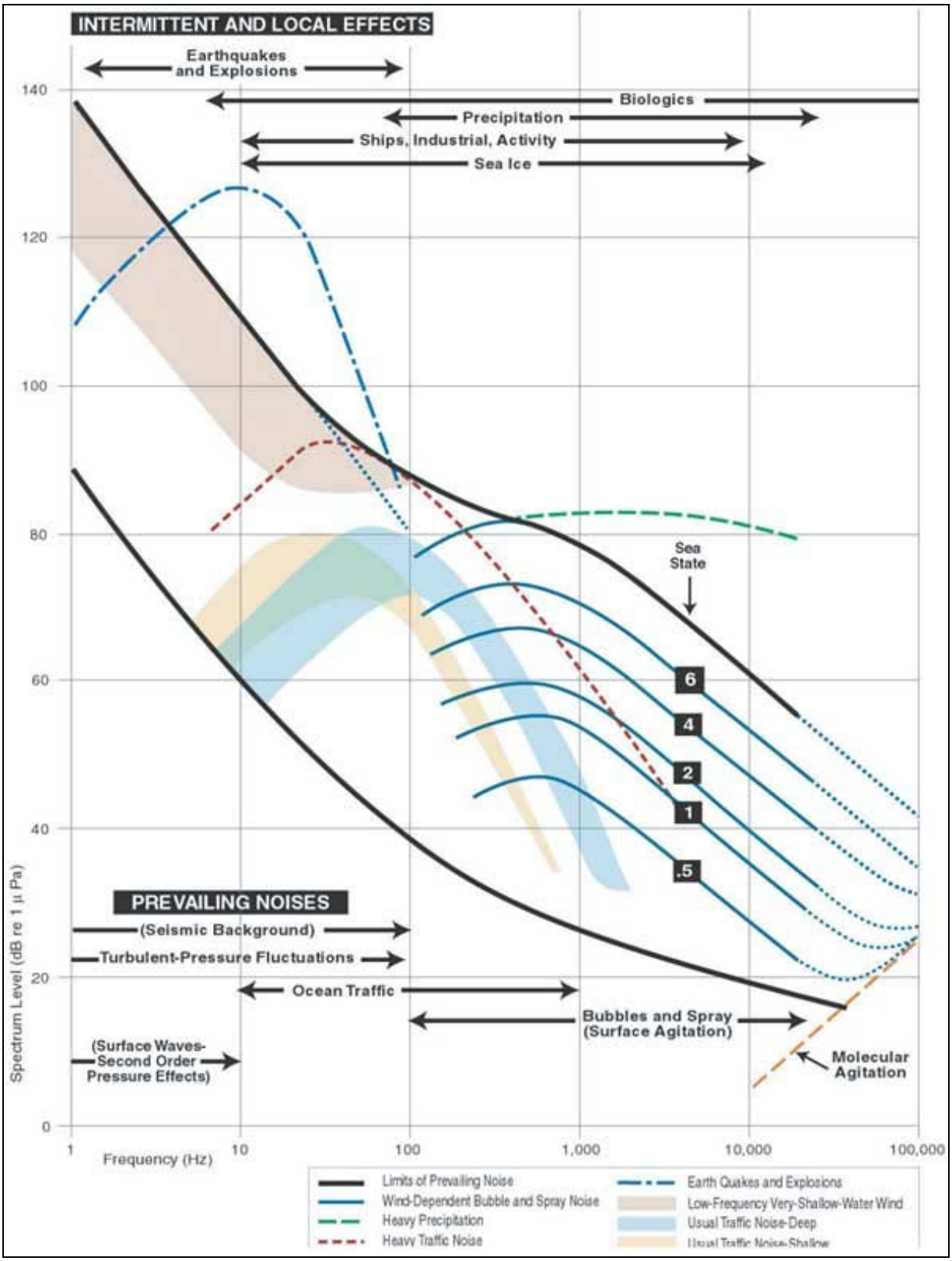
Table 3.0-5: Representative Source Levels of Common Underwater Sounds

Source	Source Level (dB re 1 µPa at 1 m)
Ice breaker ship	193[1]
Large tanker	186[1]
Seismic airgun array (32 guns)	259 (peak)[1]
Dolphin whistles	125–173[1]
Dolphin clicks	194–219[2]
Humpback whale song	144–174[3]
Snapping shrimp	183–189[4]
Sperm whale click	236[5]
Naval mid-frequency active sonar (SQS-53)	235
Lightning strike	260[6]
Seafloor volcanic eruption	255[7]

[1] (Richardson et al. 1995), [2] (Rasmussen et al. 2002), [3] (Payne and Payne 1985; Thompson et al. 1979), [4] (Au and Banks 1998), [5] (Levenson 1974; Watkins 1980), [6] (Hill 1985),[7] (Northrop 1974)
Notes: dB = decibel, m = meters, µPa = micro Pascal

3.0.4.6.1 Physical Sources of Underwater Sound

Physical processes that create sound in the ocean include rain, wind, waves, sea ice, lightning strikes at the sea surface, undersea earthquakes, and eruptions from undersea volcanoes. Generally, these sound sources contribute to a rise in the ambient sound levels on an intermittent basis. Underwater sound from rain typically is between 1 and 3 kHz. Wind produces frequencies between 100 Hz and 30 kHz, while wave-generated sound is a significant contributor in the infrasonic range (i.e., 1 - 20 Hz) (Simmonds et al. 2003). Seismic activity results in the production of low-frequency sounds that can be heard for great distances.



From National Research Council (2003), adapted from Wenz (1962)

Figure 3.0-14: Oceanic Ambient Noise Levels from 1 Hertz to 100,000 Hertz, Including Frequency Ranges for Prevalent Noise Sources

3.0.4.6.2 Biological Sources of Underwater Sound

Marine animals use sound both passively and actively in order to navigate, communicate, locate food, reproduce, and detect predators and other important environmental cues. Sounds produced by marine species can increase ambient sound levels by nearly 20 dB over the range of a few kHz (e.g., crustaceans and fish) or over the range of tens to hundreds of kHz (e.g., dolphin clicks and whistles). In fishes, reproductive activity, including courtship and spawning, accounts for the majority of sounds produced. During the spawning season, croakers (family Sciaenidae) vocalize for many hours and often dominate the acoustic environment (Ramcharitar et al. 2006). Other species, including baleen whales (Mysticetes) and toothed whales and dolphins (Odontocetes) produce a wide variety of sounds in many different behavioral contexts. These sounds can include tonal calls, clicks, whistles, and pulsed sounds, which cover a wide range of frequencies depending on the species and sound type produced. Bottlenose dolphin clicks and whistles, for instance, have a dominant frequency range of 110–130 kHz and 3.5–14.5 kHz, respectively (Au 1993). In addition, sperm whale clicks range in frequency from 0.1 kHz to 30 kHz, with dominant energy in two bands (2–4 kHz and 10–16 kHz) (Richardson et al. 1995). Blue and fin whales produce low-frequency moans at frequencies of 10–25 Hz. Colonies of snapping shrimp can generate sounds at frequencies of 2–15 kHz.

3.0.4.6.3 Anthropogenic Sources of Underwater Sound

In addition to sounds generated during Navy training and testing, other non-Navy activities also introduce similar types of anthropogenic (human-generated) sound into the ocean from a number of sources, including non-military vessel traffic, industrial operations onshore (pile driving), seismic profiling for oil exploration, oil drilling, and underwater explosions. Noise levels resulting from human activities in coastal and offshore areas are increasing; however, there are few historical records of ambient noise data to substantiate the level of increase, but see Andrew et al. (2002) and McDonald et al. (2006, 2008).

Commercial shipping is the most widespread source of human-made, low-frequency (0–1,000 Hz) noise in the oceans and may contribute more than 75 percent of all human-made sound in the sea (International Council for the Exploration of the Sea 2005), particularly in coastal areas and near shipping lanes (see Figures 3.11-1 and 3.11-2 for commercial shipping lanes in the Study Area). There are approximately 20,000 large commercial vessels at sea worldwide at any given time. Because low-frequency sounds carry for long distances, a large vessel emitting sound at 6.8 Hz can be detected 75–250 nm away (Polefka 2004). The dominant component of low-frequency ambient noise is commercial tankers, which contribute twice as much noise as cargo vessels and at least 100 times as much noise as research vessels (Hatch et al. 2008). Most of these sounds are produced as a result of propeller cavitation (when air spaces created by the motion of propellers collapse) (Southall et al. 2007).

High-intensity, low-frequency impulsive sounds are emitted during seismic surveys to determine the structure and composition of the geological formations below the sea bed to identify potential hydrocarbon reservoirs (i.e., oil and gas exploration) (Simmonds et al. 2003).

3.0.4.7 Aerial Sounds

Aerial sounds may be produced by physical, biological, or anthropogenic sources. These sounds may be transmitted across the air-water interface as well. Of the physical sources of sound, surf noise is one of the most dominant. The highest sound levels from surf are typically low frequency (below 100 Hz). Biological sources of sound can be a significant contribution to the noise level in coastal environments

such as areas occupied by highly vocal sea lions. Anthropogenic noise sources like ships, industrial sites, cars, and airplanes are also potential contributors.

3.0.5 Overall Approach to Analysis

The overall approach to analysis in this EIS/OEIS included the following general steps:

- Identification of resources for analysis
- Resource-specific impacts analysis for individual stressors
- Resource-specific impacts analysis for multiple stressors
- Examination of potential population-level impacts
- Cumulative impacts analysis
- Consideration of mitigations to reduce identified potential impacts

Navy training and testing activities in the Proposed Action may cause one or more stimuli that cause stress on a resource. Each proposed Navy activity was examined to determine its potential stressors (Table 3.0-6). Not all stressors affect every resource, nor do all proposed Navy activities produce all stressors (Table 3.0-7). The potential direct, indirect, and cumulative impacts of the Proposed Action were analyzed based on these potential stressors being present with the resource. 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. 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. Secondly, each resource was analyzed for potential impacts of individual stressors, 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. Mitigation measures are discussed in detail in Chapter 5.

In this phased 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.

Table 3.0-6: List of Stressors Analyzed

Components and Stressors for Physical Resources	
Sediments and Water Quality	
• Explosives and explosive byproducts	• Chemicals other than explosives
• Metals	• Other materials
Air Quality	
• Criteria pollutants	• Hazardous air pollutants
Components and Stressors for Biological Resources	
Acoustic Stressors	
• Sonar and other active sources	• Weapons firing, launch and impact noise
• Explosives	• Vessel noise
• Pile driving	• Aircraft noise
• Swimmer defense airguns	
Energy Stressors	
• Electromagnetic devices	
Physical Disturbance and Strike Stressors	
• Aircraft and aerial targets	• Military expended materials
• Vessels	• Seafloor devices
• In-water devices	
Entanglement Stressors	
• Fiber optic cables and guidance wires	• Parachutes
Ingestion Stressors	
• Military expended materials from munitions	
• Military expended materials other than munitions	
Secondary Stressors	
• Habitat (sediment and water quality; air quality)	
• Prey availability	
Components and Stressors for Human Resources	
Cultural Resources Stressors	
• Acoustic	
• Physical disturbance	
Socioeconomic Stressors	
• Accessibility	
• Airborne acoustics	
• Physical disturbance and strikes	
• Secondary impacts from availability of resources	
Public Health and Safety Stressors	
• Underwater energy	
• In-air energy	
• Physical interactions	
• Secondary stressors (sediments and water quality)	

Table 3.0-7: Stressors by Warfare and Testing Area

Warfare Area/Testing Area	Acoustic Stressors	Energy Stressors	Physical Disturbance and Strike Stressors	Entanglement Stressors	Ingestion Stressors	Accessibility	Underwater Energy	In-Air Energy	Physical Interactions	Secondary Stressors	
										Sediments and Water Quality	Air Quality
Training Activities											
Anti-Air Warfare	✓		✓	✓	✓	✓		✓	✓	✓	✓
Amphibious Warfare	✓		✓		✓	✓			✓	✓	✓
Strike Warfare	✓		✓		✓	✓		✓	✓	✓	✓
Anti-Surface Warfare	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Anti-Submarine Warfare	✓		✓	✓	✓	✓	✓		✓	✓	✓
Electronic Warfare	✓		✓		✓			✓	✓	✓	✓
Mine Warfare	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Naval Special Warfare	✓		✓		✓	✓	✓	✓	✓	✓	✓
Major Exercises	✓		✓	✓	✓	✓	✓		✓	✓	✓
Other Training Activities	✓		✓		✓	✓	✓		✓	✓	✓
Testing Activities											
Anti-Air Warfare	✓		✓	✓	✓	✓			✓	✓	✓
Anti-Surface Warfare	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Electronic Warfare	✓		✓		✓				✓	✓	✓
Anti-Submarine Warfare	✓		✓	✓	✓	✓	✓		✓	✓	✓
Mine Warfare	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
New Ship Construction	✓		✓	✓	✓	✓	✓		✓	✓	✓
Life Cycle Activities	✓		✓	✓	✓	✓	✓		✓	✓	✓
Shipboard Protection Systems and Swimmer Defense Testing	✓		✓		✓	✓	✓		✓	✓	✓
Unmanned Vehicle Testing	✓		✓	✓	✓	✓	✓		✓	✓	✓
SPAWAR RDT&E Testing	✓		✓		✓	✓	✓		✓	✓	✓
Office of Naval Research RDT&E	✓		✓		✓	✓	✓		✓	✓	✓
Other Testing Activities	✓		✓			✓	✓		✓	✓	✓

Notes: SPAWAR = Space and Naval Warfare Systems Command; RDT&E = Research, Development, Test, and Evaluation

3.0.5.1 Resources and Issues Evaluated

Physical resources and issues evaluated include marine sediments, marine water quality, and air quality. Biological resources (including threatened and endangered species) evaluated include marine habitats, marine mammals, sea turtles, seabirds, marine vegetation, marine invertebrates, and fish. Human resources evaluated in this EIS/OEIS include cultural resources, socioeconomics, and public health and safety.

3.0.5.2 Resources and Issues Eliminated from Further Consideration

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 would not be relevant to land use issues and no new actions are being proposed that would include relevant land use. Demographics were eliminated from further consideration because implementation of the Proposed Action would not result in a change in the demographics within the Study Area of 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 where there are no minority or low-income 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, EO 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.

3.0.5.3 Identification of Stressors for Analysis

The proposed training and testing activities were evaluated to identify specific components that could act as stressors (Table 3.0-6) by having direct or indirect impacts on the environment. This analysis included identification of the spatial variation of the identified stressors. The warfare and testing areas along with their associated environmental stressors are identified in Table 3.0-7. Matrices were prepared to identify associations between stressors, resources, training and testing activities, warfare and testing areas, range complexes, and alternatives. The following subsections describe the environmental stressors for biological resources in more detail. Each description contains a list of activities in which the stressor may occur. Refer to Appendix F (Training and Testing Activities Matrices) for more information on stressors associated with each training and testing activity. Resources that may occur or are known to occur within the Study Area and that may be exposed to the identified stressors are also listed in Appendix F. Stressors for physical resources (sediment and water quality, air 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 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.

3.0.5.3.1 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 and explosive impacts to resources in the remainder of Chapter 3 (Affected Environment and Environmental Consequences). For additional details on the properties of sound and explosives, see Section 3.0.4 (Acoustic and Explosives Primer).

3.0.5.3.1.1 Sonar and Other Active Acoustic Sources

Sonar and other non-impulsive sound sources emit sound waves into the water to detect objects, safely navigate, and communicate. Most systems operate within specific frequencies (although some harmonic frequencies may be emitted at lower sound pressure levels). Sonar use associated with anti-submarine

warfare would emit the most non-impulsive sound underwater during training and testing activities. Sonar use associated with mine warfare would also contribute a notable portion of overall non-impulsive sound. Other sources of non-impulsive sound include acoustic communications, sonar used in navigation, and other sound sources used in testing. General categories of sonar systems are described in Section 2.3.1 (Sonar and Other Acoustic Sources). Table 3.0-8 summarizes the source classes proposed for use in the Study Area during training and testing for an annual maximum year (a notional 12-month period when all annual and non-annual events could occur) under each alternative.

Table 3.0-8: Sonar and Other Active Source Classes for Each Alternative

For Annual Training and Testing Activities								
Source Class Category	Source Class	Units	Annual Hours					
			No Action Alternative		Alternative 1		Alternative 2	
			Training	Testing	Training	Testing	Training	Testing
Low-Frequency (LF) Sources that produce signals less than 1 kHz	LF4	Hours	0	2	0	42	0	52
	LF5	Hours	0	1,680	0	1,920	0	2,160
	LF6	Hours	0	0	0	192	0	192
Mid-Frequency (MF) Tactical and nontactical sources that produce signals from 1 to 10 kHz	MF1	Hours	3,461	25	11,588	169	11,588	180
	MF1K	Hours	83	0	88	17	88	18
	MF2	Hours	898	0	3,060	84	3,060	84
	MF2K	Hours	27	0	34	0	34	0
	MF3	Hours	1,036	119	2,336	350	2,336	392
	MF4	Hours	607	66	888	643	888	693
	MF5	Items	6,379	2,813	13,718	4,596	13,718	5,024
	MF6	Items	0	507	0	507	0	540
	MF8	Hours	0	2	0	2	0	2
	MF9	Hours	0	270	0	2,743	0	3,039
	MF10	Hours	0	0	0	34	0	35
	MF11	Hours	0	0	1,120	0	1,120	0
	MF12	Hours	0	0	1,094	336	1,094	336
High-Frequency (HF) Tactical and nontactical sources that produce signals greater than 10kHz but less than 180kHz	HF1	Hours	590	15	1,754	778	1,754	1,025
	HF3	Hours	0	0	0	233	0	273
	HF4	Hours	5,121	23	4,848	1,026	4,848	1,336
	HF5	Hours	0	0	0	966	0	1,094
	HF6	Hours	0	2,280	0	2,960	0	3,460
Anti-Submarine Warfare (ASW) Tactical sources used during anti-submarine warfare training and testing activities	ASW1	Hours	0	0	224	224	224	224
	ASW2[1]	Hours	0	0	0	191	0	255
	ASW2[1]	Items	1,046	2,090	1,800	2,090	1,800	2,260
	ASW3	Hours	4,492	25	16,561	1,133	16,561	1,278
	ASW4	Items	974	340	1,540	426	1,540	477

[1] The ASW2 bin contains sources that are analyzed by hours and some that are analyzed by count. There is no overlap of the numbers in the two rows.

Table 3.0-8: Sonar and Other Active Source Classes for Each Alternative (continued)

For Annual Training and Testing Activities								
Source Class Category	Source Class	Units	Annual Hours					
			No Action Alternative		Alternative 1		Alternative 2	
			Training	Testing	Training	Testing	Training	Testing
Torpedoes (TORP) Source classes associated with active acoustic signals produced by torpedoes	TORP1	Items	92	186	170	668	170	701
	TORP2	Items	321	275	400	672	400	732
Acoustic Modems (M) Transmit data acoustically through the water	M3	Hours	0	3,294	0	4,375	0	4,995
Swimmer Detection Sonar (SD) Used to detect divers and submerged swimmers	SD1	Hours	0	38	0	30	0	38
Airguns (AG) Used during swimmer defense and diver deterrent training and testing activities	AG	Items	0	5	0	4	0	5
Synthetic Aperture Sonar (SAS): Sonar in which active acoustic signals are post-processed to form high-resolution images of the seafloor	SAS1	Hours	0	1,740	0	2,280	0	2,700
	SAS2	Hours	0	2,280	0	4,320	0	4,956
	SAS3	Hours	0	2,280	0	2,880	0	3,360

Underwater sound propagation is highly dependent upon 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 (see Section 3.0.4.4, Predicting How Sound Travels).

A very simple estimate of sonar transmission loss can be calculated using the spherical spreading law, $TL = 20 \log_{10} r$, where r is the distance from the sound source and TL is the transmission loss in decibels (see Section 3.0.4.4.1 on Sound Attenuation and Transmission Loss). While a simple example is provided here for illustration, the Navy Acoustic Effects Model takes into account the influence of multiple factors to predict acoustic propagation (Marine Species Modeling Team 2012).The simplified estimate of spreading loss for a ping from a hull-mounted tactical sonar with a representative source level of 235 dB re 1 µPa is shown in Figure 3.0-15. The figure shows that sound levels drop off significantly near the source, followed by a more steady reduction with distance. Most non-impulsive sound sources used during training and testing have sound source levels lower than this example.

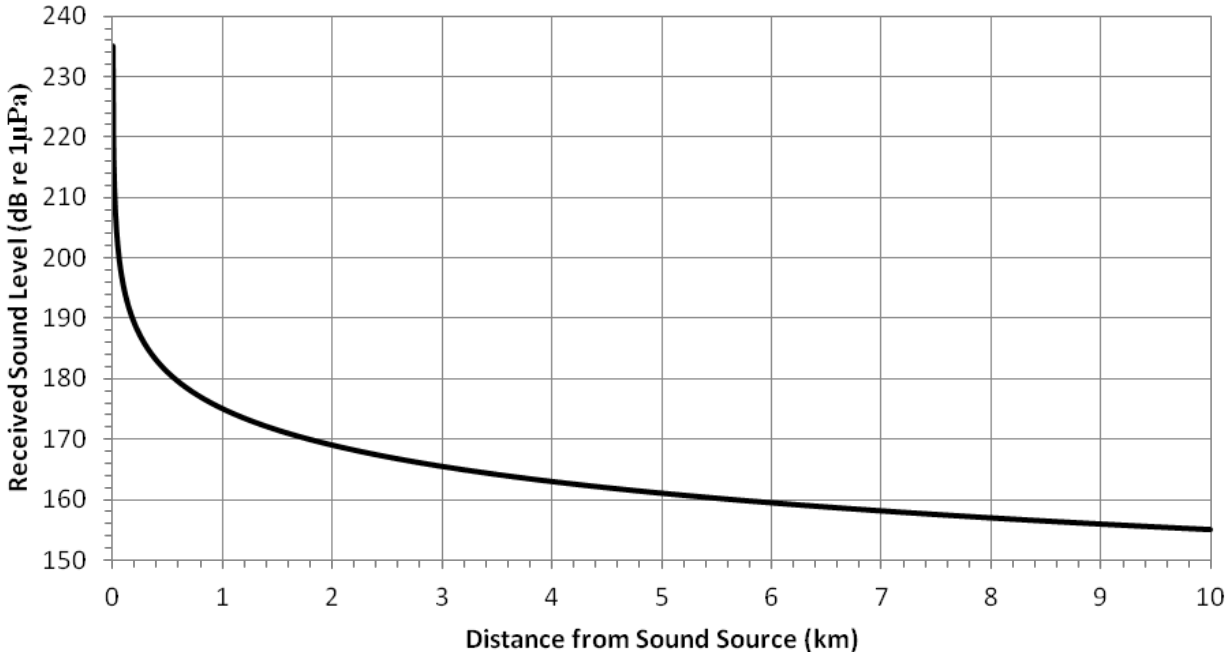


Figure 3.0-15: Estimate of Spreading Loss for a 235 dB re 1 µPa Sound Source Assuming Simple Spherical Spreading Loss

Most use of active acoustic sources involves a single unit or several units (ship, submarine, aircraft, or other platform) employing a single active sonar source in addition to sound sources used for communication, navigation, and measuring oceanographic conditions. Anti-submarine warfare activities may also use an acoustic target or an acoustic decoy.

Anti-Submarine Warfare Sonar

Sonar used in anti-submarine warfare is deployed on many platforms and are operated in various ways. Anti-submarine warfare active sonar is usually mid-frequency (1–10 kHz) because mid-frequency sound balances sufficient resolution to identify targets and distance within which threats can be identified.

- Ship tactical hull-mounted sonar contributes the largest portion of overall non-impulsive sound. Duty cycle can vary from about a ping per minute to continuously active. Sonar can be wide-ranging in a search mode or highly directional in a track mode.
- A submarine‘s mission revolves around its stealth; therefore, a submarine’s mid-frequency sonar is used infrequently because its use would also reveal a submarine’s location.
- Aircraft-deployed, mid-frequency, anti-submarine warfare systems include omnidirectional dipping sonar (deployed by helicopters) and omnidirectional sonobuoys (deployed from various aircraft), which have a typical duty cycle of several pings per minute.
- Acoustic decoys that continuously emulate broadband vessel sound or other vessel acoustic signatures may be deployed by ships and submarines.
- Torpedoes use directional high-frequency sonar when approaching and locking onto a target. Practice targets emulate the sound signatures of submarines or repeat received signals.

Most anti-submarine warfare events occur more than 12 nm from shore and within areas of the HRC and SOCAL Range Complex designated for anti-submarine warfare activities.

Most events usually occur over a limited area and are completed in less than one day, often within a few hours. Multi-day anti-submarine warfare events requiring coordination of movement and effort between multiple platforms with active sonar over a larger area occur less often, but constitute a large portion of the overall non-impulsive underwater noise that would be impacted by Navy activities. For example, the largest event, a composite training unit exercise, would have periods of concentrated, near-continuous anti-submarine warfare sonar use by several platforms during a several-week period.

Mine Warfare Sonar

Sonar used to locate mines and other small objects is typically high frequency, which provides higher resolution. Mine detection sonar is deployed at variable depths on moving platforms to sweep a suspect mined area (towed by ships, helicopters, or unmanned underwater vehicles). Mid-frequency hull-mounted sonar can also be used in an object detection mode known as “Kingfisher” mode. Mine detection sonar use would be concentrated in areas where practice mines are deployed, typically in water depths less than 200 ft. (61 m). Most events usually occur over a limited area and are completed in less than one day, often within a few hours.

Other Active Acoustic Sources

Active sound sources used for navigation and obtaining oceanographic information (e.g., depth, bathymetry, and speed) are typically directional, have high duty cycles, and cover a wide range of frequencies, from mid frequency to very high frequency. These sources are similar to the navigation systems on standard large commercial and oceanographic vessels. Sound sources used in communications are typically high frequency or very high frequency. These sound sources could be used by vessels during most activities and while transiting throughout the Study Area.

Use of Sonar During Training and Testing

While most non-impulsive sound sources are used beyond nearshore waters, some use would occur nearshore in inland waters such as bays, while pierside, or while in transit in and out of port. These activities include sonar maintenance, object detection/mine countermeasures, and navigation.

Most non-impulsive sound stressors associated with testing events, and about half of non-impulsive sound stressors associated with training events, involve a single unit or several units (ship, submarine, aircraft, or other platform) employing a single active sonar source in addition to sound sources used for communication, navigation, and measuring oceanographic conditions. Anti-submarine warfare activities may also use an acoustic target or an acoustic decoy. These events usually occur over a limited area and are completed in less than one day, often within a few hours.

Multiday anti-submarine warfare events requiring coordination of movement and effort between multiple platforms with active sonar over a larger area occur less often, but constitute a large portion of overall non-impulsive underwater noise imparted by Navy activities. Approximately half of the non-impulsive sound stressors generated during training events occur during multiplatform anti-submarine warfare events. One event of this type, the submarine commander’s course training event, occurs up to two times per year in the Hawaii OPAREA off of Maui.

3.0.5.3.1.2 Explosives

Explosive detonations during training and testing activities are associated with high-explosive ordnance, including bombs, missiles, naval gun shells, torpedoes, mines, demolition charges, and explosive sonobuoys. Most explosive detonations during training and testing involving the use of high-explosive

ordnance, including bombs, missiles, and naval gun shells, would occur in the air or near the water's surface. Explosives associated with torpedoes and explosive sonobuoys would occur in the water column; mines and demolition charges could occur near the surface, in the water column, or the ocean bottom. Most detonations would occur in waters greater than 200 ft. (61 m) in depth, and greater than 3 nm from shore, although mine warfare, demolition, and some testing detonations could occur in shallow water close to shore. Detonations associated with Anti-Submarine Warfare would typically occur in waters greater than 600 ft. (182.9 m) depth. The numbers of explosions in each explosive source class proposed under each alternative are shown in Table 3.0-9 based on an annual maximum year (a notional 12-month period when all annual and non-annual events could occur) under each alternative.

Table 3.0-9: Explosives for Training and Testing Activities in the Hawaii-Southern California Training and Testing Study Area

Explosives	Location – Range Complex	Training Activities (Annual In-Water Detonations)			Testing Activities (Annual In-Water Detonations)		
		No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
E1 (0.1 lb.–0.25 lb. NEW)	Hawaii	310	6,340	6,340	0	1,400	1,750
	Southern California	1,498	13,180	13,180	1,501	11,400	12,751
	Transit Corridor	0	320	320	0	0	0
	Total	**1,808**	**19,840**	**19,840**	**1,501**	**12,800**	**14,501**
E2 (0.26 lb.–0.5 lb. NEW)	Hawaii	258	302	302	0	0	0
	Southern California	864	742	742	0	0	0
	Transit Corridor	0	0	0	0	0	0
	Total	**1,122**	**1,044**	**1,044**	**0**	**0**	**0**
E3 (0.6 lb.–2.5 lb. NEW)	Hawaii	3,621	564	564	139	288	379
	Southern California	15,325	2,456	2,456	2,203	2,400	2,611
	Transit Corridor	0	0	0	0	0	0
	Total	**18,946**	**3,020**	**3,020**	**2,342**	**2,688**	**2,990**
E4 (>2.5 lb.–5 lb. NEW)	Hawaii	638	482	482	174	168	204
	Southern California	82	186	186	529	480	549
	Transit Corridor	0	0	0	0	0	0
	Total	**720**	**668**	**668**	**703**	**648**	**753**
E5 (>5 lb.–10 lb. NEW)	Hawaii	5,828	2,490	2,490	0	0	0
	Southern California	10,987	5,644	5,644	0	184	202
	Transit Corridor	0	20	20	0	0	0
	Total	**16,815**	**8,154**	**8,154**	**0**	**184**	**202**
E6 (>10 lb.–20 lb. NEW)	Hawaii	39	59	59	0	7	7
	Southern California	226	479	479	5	27	30
	Transit Corridor	0	0	0	0	0	0
	Total	**265**	**538**	**538**	**5**	**34**	**37**

Table 3.0-9: Explosives for Training and Testing Activities in the Hawaii-Southern California Training and Testing Study Area (continued)

Explosives	Location – Range Complex	Training Activities (Annual In-Water Detonations)			Testing Activities (Annual In-Water Detonations)		
		No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
E7 (>20 lb.–60 lb. NEW)	Hawaii	33	40	40	0	18	21
	Southern California	258	367	367	0	0	0
	Transit Corridor	0	0	0	0	0	0
	Total	**291**	**407**	**407**	**0**	**18**	**21**
E8 (>60 lb.–100 lb. NEW)	Hawaii	20	46	46	3	4	4
	Southern California	9	18	18	0	7	8
	Transit Corridor	0	0	0	0	0	0
	Total	**29**	**64**	**64**	**3**	**11**	**12**
E9 (>100 lb.–250 lb. NEW)	Hawaii	12	12	12	0	0	0
	Southern California	4	4	4	0	0	0
	Transit Corridor	0	0	0	0	0	0
	Total	**16**	**16**	**16**	**0**	**0**	**0**
E10 (>250 lb.–500 lb. NEW)	Hawaii	2	6	6	4	4	5
	Southern California	9	13	13	0	24	26
	Transit Corridor	0	0	0	0	0	0
	Total	**11**	**19**	**19**	**4**	**28**	**31**
E11 (>500 lb.–650 lb. NEW)	Hawaii	6	6	6	3	4	4
	Southern California	2	2	2	0	9	10
	Transit Corridor	0	0	0	0	0	0
	Total	**8**	**8**	**8**	**3**	**13**	**14**
E12 (>650 lb.–1000 lb. NEW)	Hawaii	44	62	62	0	0	0
	Southern California	162	162	162	0	0	0
	Transit Corridor	0	0	0	0	0	0
	Total	**206**	**224**	**224**	**0**	**0**	**0**
E13 (>1000 lb.–1,740 lb. NEW)	Hawaii	0	0	0	0	0	0
	Southern California	9	9	9	0	0	0
	Transit Corridor	0	0	0	0	0	0
	Total	**9**	**9**	**9**	**0**	**0**	**0**

Notes: NEW = Net Explosive Weight, lb. = pounds

Explosives in the water introduce loud, impulsive, broadband sounds into the marine environment. Three source parameters influence the effect of an explosive: (1) the weight of the explosive warhead, (2) the type of explosive material, and (3) the detonation depth. The net explosive weight, the explosive

power of a charge expressed as the equivalent weight of TNT, accounts for the first two parameters. The properties of explosive detonations are discussed in Section 3.04 (Acoustic and Explosives Primer). Table 3.0-10 shows the depths at which representative explosive source classes are assumed to detonate underwater for purposes of analysis.

Table 3.0-10: Representative Ordnance, Net Explosive Weights, and Detonation Depths

Representative Ordnance	Explosive Source Class (Net Explosive Weight)	Representative Underwater Detonation Depth[1]
Medium-caliber projectiles	E1 (0.1-0.25 lb.)	1 m (3 ft.)
Medium-caliber projectiles	E2 (0.26-0.5 lb.)	1 m (3 ft.)
Large-caliber projectiles	E3 (0. 6-2.5 lb.)	1 m (3 ft.)
Improved extended echo ranging sonobuoy	E4 (2.6-5 lb.)	20 m (66 ft.), 198 m (650 ft.)
5 in. projectiles	E5 (6-10 lb.)	1 m (3 ft.)
demo block/shaped charge	E7 (21-60 lb.)	15 m (50 ft.)
500 lb. bomb	E9 (101-250 lb.)	1 m (3 ft.)
650 lb. mine	E11 (501-650 lb.)	6 m (20 ft.), 10 m (33 ft.)
2,000 lb. bomb	E12 (651-1,000 lb.)	1 m (3 ft.)

[1] Underwater detonation depths listed are those assumed for purposes of acoustic impacts modeling. Detonations assumed to occur at a depth of 3 ft. (1 m) include detonations that would actually occur at or just above the water surface.
Notes: ft. = feet, lb. = pounds, m = meters

In general, explosive events would consist of a single explosion or multiple explosions over a short period. During training, all large, high-explosive bombs would be detonated near the surface over deep water. Bombs with high-explosive ordnance would be fused to detonate on contact with the water. Other detonations would occur near but above the surface upon impact with a target; these detonations are conservatively assumed to occur at a depth of 3.3 ft. (1 m) for purposes of analysis. Detonations of projectiles during anti-air warfare would occur far above the water surface.

Since most explosive sources used in military activities are munitions that detonate essentially upon impact, the effective source depths are quite shallow and, therefore, the surface-image interference effect can be pronounced (see Section 3.04, Acoustic and Explosives Primer). This effect would reduce peak pressures and potential impacts near the water surface.

3.0.5.3.1.3 Pile Driving

Construction during training of the elevated causeway system, a temporary pier allowing offloading of supply ships, would require pile driving and pile removal. This training activity would occur four times per year under the No Action Alternative, Alternative 1, and Alternative 2 at the Silver Strand Training Complex or Camp Pendleton Amphibious Assault Area. 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. Construction of the elevated causeway system would involve intermittent impact pile driving of 24-inch (in.), uncapped, steel pipe piles over approximately two weeks. Crews work 24 hours a day and can drive approximately eight piles in that period. Each pile takes about 10 minutes to drive. When training events that use the elevated causeway system are complete, the structure would be removed, using vibratory methods over approximately 6 days. Crews can remove about 14 piles per 24-hour period, each taking about 6 minutes to remove.

Impact pile driving creates repetitive impulsive sound. An impact pile driver generally operates in the range of 36 to 50 blows per minute. Vibratory pile driving creates a nearly continuous sound made up of

a series of short duration rapid impulses at a much lower source level than impact pile driving. The sounds are emitted both in the air and in the water.

The intensity of pile driving sounds is influenced by the type of piles, hammers, and the physical environment in which the activity takes place. Table 3.0-11 shows representative airborne pile driving sound pressure levels that have been recorded from other construction activities in recent years. Although the airborne sound emitted during pile driving and removal would be influenced by site characteristics, these represent reasonable sound pressure levels that could be anticipated.

Table 3.0-11: Airborne Sound Pressure Levels from Similar Pile Driving Events

Project & Location	Pile Size & Type	Installation Method	Water Depth	Measured Sound Pressure Levels
Friday Harbor Ferry Terminal, WA[1]	24 in. Steel Pipe Pile	Impact	~12 m (40 ft.)	112 dB re: 20 µPa (rms) at 160 ft.
Keystone Ferry Terminal, WA[2]	30 in. Steel Pipe Pile	Vibratory	~9 m (30 ft.)	98 dB re: 20 µPa (rms) at 36 ft.

[1] Laughlin 2005, [2] Laughlin 2010
Notes: dB = decibel, in. = inch, rms = root mean square, WA = Washington, m = meters, ft. = feet, µPa = micro Pascal

Pile driving for elevated causeway system training 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 Hz. Average underwater sound levels for driving piles similar to those that would be installed for elevated causeway systems are shown in Table 3.0-12.

Table 3.0-12: Average Pile Driving Underwater Sound Levels

Pile Size &Type	Installation Method	Water Depth	Average Sound Pressure Level (peak)*	Average Sound Pressure Level (rms)*
0.61 m (24 in.) Steel Pipe Pile	Impact	5 m (15 ft.)	203 dB re: 1 µPa (peak) at 10 m	190 dB re: 1 µPa (rms) at 10 m
1 m (36 in.) Steel Pipe Pile	Vibratory	5 m (15 ft.)	180 dB re: 1 µPa (peak) at 10 m	170 dB re: 1 µPa (rms) at 10 m

* California Department of Transportation (CALTRANS) 2009
Notes: dB = decibel, ft. = foot, in. = inch, m = meter, µPa = micro Pascal, re:referenced to, rms = root mean square

3.0.5.3.1.4 Swimmer Defense Airguns

Swimmer defense airguns would be used for pierside integrated swimmer defense testing at pierside locations at Naval Base San Diego. Pierside integrated swimmer defense testing involves a limited number of impulses from a small airgun in inland waters around Navy piers. Airguns would be fired a limited number of times (up to 100) during each activity at an irregular interval as required for the testing objectives. These areas adjacent to Navy pierside integrated swimmer defense testing are industrialized, and the waterways carry a high volume of vessel traffic in addition to Navy vessels using the pier.

Underwater impulses would be generated using small (approximately 60 cubic inch [in.^{3}]) airgun, which are essentially a stainless steel tube charged with high-pressure air via a compressor. An impulsive sound is generated when the air is almost instantaneously released into the surrounding water, an effect similar to popping a balloon in air. Generated impulses would have short durations, typically a few hundred milliseconds. The root-mean-squared sound pressure level and sound exposure level at a distance 1 m from the airgun would be approximately 200–210 dB re 1 µPa and 185–195 dB re 1 µPa^2-s, respectively. Swimmer defense airguns lack the strong shock wave and rapid pressure increase that would be expected from explosive detonations.

3.0.5.3.1.5 Weapons Firing, Launch, and Impact Noise

Noise associated with weapons firing and the impact of non-explosive practice munitions could happen at any location within the Study Area but generally would occur at locations greater than 12 nm from shore for safety reasons. These training and testing events would occur in areas of the HRC and SOCAL Range Complex designated for anti-surface warfare and similar activities as well as in the Transit Corridor during ship transits between the HRC and SOCAL Range Complex. Testing activities involving weapons firing noise would be those events involved with testing weapons and launch systems. These activities would also take place throughout the Study Area primarily in the same locations as the training events occur, but with fewer events taking place in the Transit Corridor.

The firing of a weapon may have several components of associated noise. Firing of guns could include sound generated by firing the gun (muzzle blast), vibration from the blast propagating through a ship's hull, and sonic booms generated by the projectile flying through the air (Table 3.0-13). Missiles and targets would produce noise during launch. In addition, the impact of non-explosive practice munitions at the water surface can introduce sound into the water. Detonations of high-explosive projectiles are considered in Section 3.0.4.1.4 (Categories of Sound).

Table 3.0-13: Representative Weapons Noise Characteristics

Noise Source	Sound Level
In-Water	
Naval Gunfire Muzzle Noise (5-inch/54-caliber)	Approximately 200 dB re 1 µPa directly under gun muzzle at 5 ft. (1.5 m) below the water surface[1]
Airborne	
Naval Gunfire Muzzle Noise (5-inch/54-caliber)	178 dB re 20 µPa directly below the gun muzzle above the water surface[1]
Hellfire Missile Launch from Aircraft	149 dB re 20 µPa at 15 ft. (4.5 m)[2]
7.62-millimeter M-60 Machine Gun	90 dBA re 20 µPa at 50 ft. (15 m)[3]
0.50-caliber Machine Gun	98 dBA re 20 µPa at 50 ft. (15 m)[3]

[1] Yagla and Stiegler 2003
[2] U.S Department of the Army 1999
[3] Investigative Science and Engineering, Inc. 1997
Notes: db = decibel; dBA = decibel, A-weighted; ft. = feet; µPa = micro Pascal; re = referenced to; m = meters

Naval Gunfire Noise

Firing a ship deck gun produces a muzzle blast in air that propagates away from the muzzle in all directions, including toward the water surface. As explained in Section 3.0.4 (Acoustic and Explosives Primer) most sound enters the water in a narrow cone beneath the sound source (within 13° of vertical). In-water sound levels were measured during the muzzle blast of a 5 in. deck-mounted gun, the largest

caliber gun currently used in proposed Navy activities. The highest sound level in the water (on average 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 (U.S. Department of the Navy 2000; Yagla and Stiegler 2003). The average impulse at that location was 19.6 Pa-s. The corresponding average peak in-air pressure was 178 dB re 20 µPa, measured at the water surface below the firing point.

Gunfire also sends energy through the ship structure, into the water, and away from the ship. This effect was investigated in conjunction with the measurement of 5-in. gun blasts described above. The energy transmitted through the ship to the water for a typical round was about 6 percent of that from the air blast impinging on the water. Therefore, sound transmitted from the gun through the hull into the water is a minimal component of overall weapons firing noise.

The projectile shock wave 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 (Pater 1981). Measurements of a 5 in. projectile shock wave ranged from 140 to 147 dB re 20 µPa taken at the surface at 0.59 nm distance from the firing location and 10° off the line of fire for safety (approximately 623 ft. [190 m] from the shell's trajectory). Sound level intensity decreases with increased distance from the firing location and increased angle from the line of fire (Pater 1981). Like sound from the gun firing blast, sound waves from a projectile in flight would enter the water primarily in a narrow cone beneath the sound source. The region of underwater sound influence from a single traveling shell would be relatively narrow, the duration of sound influence would be brief at any point, and sound level would diminish as the shell gains altitude and loses speed. Multiple, rapid gun firings would occur from a single firing point toward a target area. Vessels participating in gunfire activities would maintain enough forward motion to maintain steerage, normally at speeds of a few knots. Acoustic impacts from weapons firing would often be concentrated in space and duration.

Launch Noise

Missiles can be rocket or jet propelled. 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. Launch noise level for the Hellfire missile, which is launched from aircraft, is about 149 dB re 20 µPa at 14.8 ft. (4.5 m) (U.S Department of the Army 1999).

Non- Explosive Munitions Impact Noise

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). 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. Sound associated with impact events is typically of low frequency (less than 250 Hz) and of short duration.

3.0.5.3.1.6 Vessel Noise

Naval vessels (including ships, small craft, and submarines) would produce low-frequency, broadband underwater sound. In the West Coast Exclusive Economic Zone, Navy ships contribute approximately 1 percent of the broadband noise generated by large military and non-military vessels. The vast majority (89 percent) of broadband noise is produced by non-military foreign flagged vessels. In the SOCAL OPAREA, U.S. Navy vessels contribute only 4 percent of the broadband noise generated in the OPAREA by large vessels (Mintz and Filadelfo 2011). Overall, naval traffic is often a minor component of total vessel traffic (Mintz and Filadelfo 2011; Mintz and Parker 2006).

Exposure to vessel noise would be greatest in the areas of highest naval vessel traffic. In an attempt to determine traffic patterns for Navy and non-Navy vessels for the SOCAL portion of the Study Area, a review by the Center for Naval Analysis (Mintz and Parker 2006) was conducted on 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 65 ft. [20 m] in length), was heaviest near the major shipping port of Los Angeles and could be seen in the east to west and north to south international shipping lanes (Figure 3.0-16).

Subsequent recent analysis by Mintz (2012) demonstrated that in 2009, within the boundaries of the Study Area, there was a total of 971,214 vessel hours and the Navy accounted for 96,685 of those hours or approximately 10 percent of the total. Military vessels would comprise an even smaller proportion of total vessels if smaller vessels (less than 65 ft. [20 m] in length) were included (Mintz and Filadelfo 2011).

Commercial vessel traffic, which included cargo vessels, bulk carriers, passenger vessels, and oil tankers (all over 65 ft. [20 m] in length), was heaviest near and between the major shipping ports along the U.S. west coast, including San Diego, Los Angles, San Francisco, and Seattle. Vessel traffic continued to be heavy along the Mexican coast as commercial vessels transited to the Panama Canal. Well defined commercial transit routes extend from the U.S. west coast to Hawaii and international destinations (e.g., Japan). Commercial vessel traffic between the Panama Canal and the Hawaiian Islands is heavier than commercial traffic between the U.S. west coast and Hawaii (Mintz 2012). Compared to coastal vessel activity, there was relatively little concentration of vessels in the other portions of the Study Area (Mintz and Parker 2006).

Radiated noise from Navy ships ranges over several orders of magnitude. The quietest Navy warships radiate much less broadband noise than a typical fishing vessel, while the loudest Navy ships are almost on par with large oil tankers (Mintz and Filadelfo 2011). For comparison, a typical commercial cargo vessel radiates broadband noise at a source level around 172 dB re 1 µPa and a typical fishing vessel radiates noise at a source level of about 158 dB re 1 µPa (Richardson et al. 1995; Urick 1983). Typical large vessel ship-radiated noise is dominated by tonals related to blade and shaft sources at frequencies below about 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) (Richardson et al. 1995; Urick 1983).

The acoustic signatures of naval vessels is classified information. Anti-submarine warfare platforms (such as DDGs and CGs) 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 platforms are much quieter than Navy oil tankers, for example, which have a smaller presence but contribute substantially more broadband noise than anti-submarine warfare platforms (Mintz and Filadelfo 2011). Sound produced by vessels will typically increase with speed. During training, speeds of most larger naval vessels generally range from 10 to 15 knots; however, ships will, on occasion, operate at higher speeds within their specific operational capabilities.

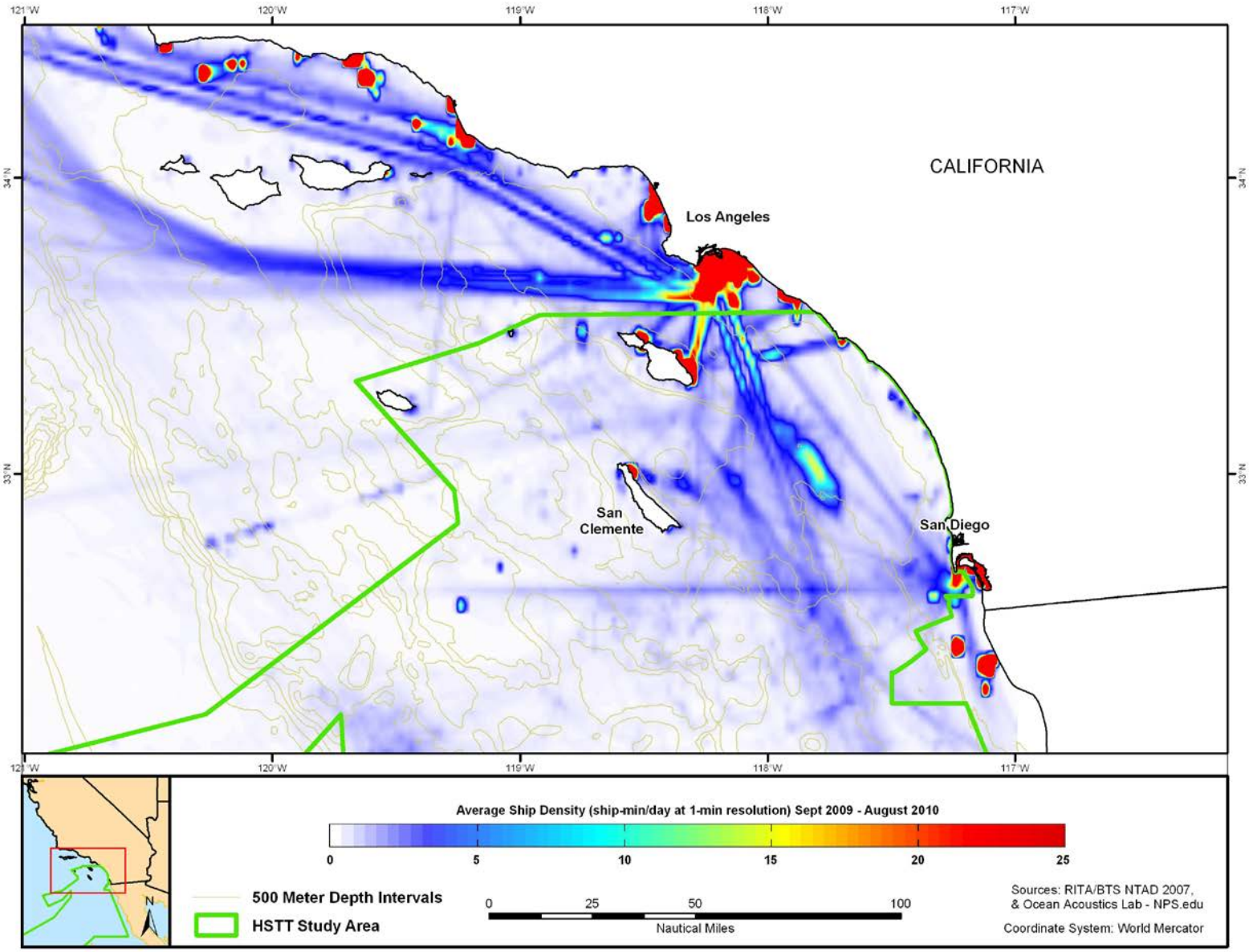


Figure 3.0-16: Average Ship Density in Southern California, September 2009 to August 2010

A variety of smaller craft, such as service vessels for routine operations and opposition forces used during training events, would be operating within the Study Area. These small craft types, sizes, and speeds vary, but in general, they will emit higher-frequency noise than larger ships.

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 days within a given area. Activities involving vessel movements occur intermittently and are variable in duration, ranging from a few hours to up to two weeks. 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 minimal because these areas typically have large amounts of commercial and recreational vessel traffic.

3.0.5.3.1.7 Aircraft Overflight Noise

Fixed- 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. Aircraft used in training and testing generally have reciprocating, 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. Takeoffs and landings occur at established airfields as well as on vessels at sea throughout the Study Area. Most aircraft noise would be produced around air stations in the range complexes. Military activities involving aircraft generally are dispersed over large expanses of open ocean but can be highly concentrated in time and location. Source levels for some typical aircraft used during training and testing in the Study Area are shown in Table 3.0-14.

Table 3.0-14: Representative Aircraft Sound Characteristics

Noise Source	Sound Level
In-Water	
F/A-18 Subsonic at 1,000 ft. (300 m) Altitude	148 dB re 1 µPa at 6 ft. (2 m) below water surface[1]
F/A-18 Subsonic at 10,000 ft. (3,000 m) Altitude	128 dB re 1 µPa at 6 ft. (2 m) below water surface[1]
H-60 Helicopter Hovering at 50 ft. (15 m) Altitude	Approximately 125 dB re 1 µPa at 3 ft. (1 m) below water surface
Airborne	
Jet Aircraft under Military Power	144 dBA re 20 µPa at 50 ft. (15 m) from source[2]
Jet Aircraft under Afterburner	148 dBA re 20 µPa at 50 ft. (15 m) from source[2]
H-60 Helicopter Hovering	90 dBA re 20 µPa at 50 ft. (15 m) from source[3]

[1] Eller and Cavanagh 2000
[2] U.S. Department of the Navy 2009
[3] Bousman and Kufeld 2005
Notes: dB = decibel; dBA = decibel, A-weighted; ft. = foot; m = meter; µPa = micro Pascal; re = referenced to

Fixed-Wing Aircraft

Noise generated by fixed-wing aircraft is transient in nature and extremely variable in intensity. Most fixed-wing aircraft sorties would occur above 3,000 ft. (900 m). Air combat maneuver altitudes generally range from 5,000 to 30,000 ft. (1.5 to 9.1 km) and typical airspeeds range from very low (less than 100 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 dBA (based on an FA-18 aircraft flying at

an altitude of 5,000 ft. [1,500 m] and at a subsonic airspeed [400 knots]) (U.S. Department of the Navy 2009). 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.

Helicopter unit level training typically entails a high volume of 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 to 100 ft. (23 to 31 m). 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.

Underwater Transmission of Aircraft Noise

Sound generated in air is transmitted to water primarily in a narrow area directly below the aircraft (see Section 3.0.4 Acoustic and Explosives Primer). A sound wave propagating from an aircraft must enter the water at an angle of incidence of 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 propagation and levels of underwater noise from passing aircraft. For low-altitude flights, sound levels reaching the water surface would be higher, but the transmission area would be smaller. As an aircraft gains altitude, sound reaching the water surface will diminishes, but the possible transmission area increases. Estimates of underwater sound pressure level are provided for representative aircraft in Table 3.0-14.

Underwater sound from aircraft overflights has been modeled for some airframes. Eller and Cavanagh (2000) modeled underwater sound pressure level as a function of time at various depths (2, 10, and 50 m) for F/A-18 Hornet aircraft subsonic overflights (250 knots) at various altitudes (300, 1,000, and 3,000 m). For the worst modeled case of an F/A-18 at the lowest altitude (300 m), the sound level at 2 m below the surface peaked at 152 dB re 1 µPa, and the sound level at 50 m below the surface peaked at 148 dB re 1 µPa. When F/A-18 flight was modeled at 3,000 m altitude, peak sound level at 2 m depth dropped to 128 dB re 1 µPa.

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 usually limited to altitudes above 30,000 ft. (9,100 m) or locations more than 30 nm from shore. Several factors influence sonic booms: weight, size, 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 and louder than those of smaller, lighter aircraft. Consequently, the larger and heavier the aircraft, the stronger the shock waves (U.S. Department of the Navy 2007).

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. (1.6 km) for each 1,000 ft. (300 m) of altitude. For example, an aircraft flying supersonic straight and level at 50,000 ft. (15,000 m) can produce a sonic boom carpet about 50 miles (80 km) 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 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 2007).

F/A-18 Hornet supersonic flight was modeled to obtain peak sound pressure levels and energy flux density at the water surface and at depth (Laney and Cavanagh 2000). These results are shown in Table 3.0-15.

Table 3.0-15: Sonic Boom Underwater Sound Levels Modeled for F/A-18 Hornet Supersonic Flight

Mach Number*	Aircraft Altitude (km)	Peak Pressure (dB re 1 μPa)			Energy Flux Density (dB re 1 μPa^2-s)		
		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: dB = decibel, km = kilometer, m = meter, μPa = micro Pascal, μPa^2-s = squared micro Pascal-second, re = referenced to

3.0.5.3.2 Energy Stressors

This section describes the characteristics of energy introduced into the water through naval training and testing and the relative magnitude and location of these activities to provide the basis for analysis of potential electromagnetic and laser impacts to resources in the remainder of Chapter 3.

3.0.5.3.2.1 Electromagnetic Devices

Electromagnetic energy emitted from magnetic influence mine neutralization systems is analyzed in this document. The training and testing activities that involve the use of magnetic influence mine neutralization systems are detailed in Table 3.0-16 through Table 3.0-18.

Table 3.0-16: Training Activities That Involve the Use of Electromagnetic Devices

Training
Mine Warfare
• Mine Countermeasure – Towed Mine Neutralization • Civilian Port Defense

Table 3.0-17: Testing Activities That Involve the Use of Electromagnetic Devices

Testing
Mine Warfare
• Airborne Towed Minesweeping Test • Mine Countermeasure/Neutralization Testing

Table 3.0-18: Annual Number and Location of Electromagnetic Energy Events

Activity Area	Training			Testing		
	No Action	Alternative 1	Alternative 2	No Action	Alternative 1	Alternative 2
HRC	0	1	1	0	0	0
SOCAL	240	241	241	15	27	31
SSTC	100	100	100	0	0	0
Total	**340**	**342**	**342**	**15**	**27**	**31**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex), SSTC = Silver Strand Training Complex

The majority of devices involved in the activities described above 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." An example of a representative device is the Organic Airborne and Surface Influence Sweep that would be used by a MH-60S helicopter at sea. The Organic Airborne and Surface Influence Sweep is towed from a forward flying helicopter and works by 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 relative to seawater. This amount of voltage is comparable to two automobile batteries. Since saltwater is an excellent conductor, only very moderate voltages of 35 volts (capped at 55 volts) are required to generate the current. These small levels represent no danger of electrocution in the marine environment, because the difference in electric charge is very low in saltwater.

The static magnetic field generated by the electromagnetic devices is of relatively minute strength. Typically, the maximum magnetic field generated would be approximately 23 gauss (G). 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 (150–200 G) and a standard household can opener (up to 4 G at 4 in.). The strength of the electromagnetic field decreases quickly away from the cable. The magnetic field generated at a distance of 13.12 ft. (4 m) from the source is comparable to the earth's magnetic field, which is approximately 0.5 G. The strength of the field at just under 26 ft. (8 m) is only 40 percent of the earth's field, and only 10 percent at 79 ft. (24 m). At a radius of 656 ft. (200 m) the magnetic field would be approximately 0.002 G (U.S. Department of the Navy 2005).

The kinetic energy weapon (commonly referred to as the rail gun) is under development and will likely 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 a second, therefore, any electromagnetic energy released would be done so over a very short period. Also, the system would likely be shielded so as not to affect shipboard controls and

systems. The amount of electromagnetic energy released from this system would likely be low and contained on the surface vessel. Therefore, this device is not expected to result in any impacts and will not be further analyzed for biological resources in this document.

3.0.5.3.2.2 Lasers

Laser devices 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 guide weapons, and to detect or classify mines. High energy lasers are used as weapons to disable surface targets. No high energy lasers would be used in the Study Area as part of the Proposed Action, and are not discussed further.

Low Energy Lasers

Within the category of low energy lasers, the highest potential level of exposure would be from 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 (Swope 2010). The assessment determined that the maximum potential for laser exposure is at the ocean's surface, where laser intensity is greatest (Swope 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 mammal or sea turtle. However, an animal's eye would have to be exposed to a direct laser beam for at least 10 seconds or longer to sustain damage. Swope (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 analyzed further in this document as a stressor to biological resources.

3.0.5.3.3 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 relative magnitude and location of these activities to provide the basis for analyzing the potential physical disturbance and strike impacts to resources in the remainder of Chapter 3.

3.0.5.3.3.1 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 5 to over 300 meters. Table 3.0-19 provides examples of the types of vessels, length, and speeds used in both testing and training activities. The U.S. Navy Fact Files on the World Wide Web 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 generally operate at speeds in the range of 10 to 15 knots, and submarines generally operate at speeds in the range of 8 to 13 knots. Small craft (for purposes of this discussion, less than 40 ft. [12 m] in length), which are all support craft, have much more variable speeds (dependent on the mission). While these speeds are 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. Conversely, 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 such as aircraft carriers, amphibious assault ships and the joint high speed vessel (which will operate at an average speed of 35 knots) where vessels would operate at higher speeds.

Table 3.0-19: Representative Vessel Types, Lengths, and Speeds

Type	Example(s)	Length	Typical Operating Speed	Max Speed
Aircraft Carrier	Aircraft Carrier (CVN)	>300 m	10–15 knots	30+ knots
Surface Combatant	Cruisers (CG), Destroyers (DDG), Frigates (FFG), Littoral Combat Ships (LCS)	100–200 m	10–15 knots	30+ knots
Amphibious Warfare Ship	Amphibious Assault Ship (LHA, LHD), Amphibious Transport Dock (LPD), Dock Landing Ship (LSD)	100–300 m	10–15 knots	20+ 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)	5–45 m	Variable	20 knots
Support Craft/Other – Specialized High Speed	High Speed Ferry/Catamaran; Patrol Coastal Ships (PC); Rigid Hull Inflatable Boat (RHIB)	20–40 m	Variable	50+ knots
Submarines	Fleet Ballistic Missile Submarines (SSBN), Attack Submarines (SSN), Guided Missile Submarines (SSGN)	100–200 m	8–13 knots	20+ knots

Notes: > greater than, m = meters

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 up 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, range complexes and testing ranges.

In an attempt to determine traffic patterns for Navy and non-Navy vessels, the Center for Naval Analysis (Mintz and 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 65 ft. [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 and 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 and 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 and Filadelfo (2011) and indicated that along the Pacific U.S. Exclusive Economic Zone, Navy vessels accounted for slightly less than 6 percent of the total large vessel traffic (from estimated vessel hours) in that area. In the SOCAL 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.

The training and testing activities listed in Table 3.0-20 through Table 3.0-29 involve the use of vessels. Major training events involving multiple vessels are not accounted for in Table 3.0-20 through Table 3.0-29 as these events are accounted for elsewhere within the warfare areas and not as stand-alone activities.

Table 3.0-20: Training Activities that Involve the Use of Aircraft Carriers

Training
Anti-Air Warfare
• Air Defense Exercises
Anti-Submarine Warfare
• Anti-Submarine Warfare for Composite Training Unit Exercise • Anti-Submarine Warfare for Joint Task Force Exercise/Sustainment Exercise

Table 3.0-21: Testing Activities that Involve the Use of Aircraft Carriers

Testing
Other Testing Activities
• Test and Evaluation Catapult Launch
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Countermeasure Testing

Table 3.0-22: Training Activities that Involve the Use of Surface Combatants

Training
Anti-Air Warfare
• Air Defense Exercises • Gunnery Exercise (Surface-to-Air) – Large-Caliber • Gunnery Exercise (Surface-to-Air) – Medium-Caliber • Missile Exercise (Surface-to-Air)
Amphibious Warfare
• Fire Support Exercise-Land-based target • Fire Support Exercise – At Sea • Expeditionary Fires Exercise/Supporting Arms Coordination Exercise
Anti-Surface Warfare
• Maritime Security Operations • Gunnery Exercise Surface-to-Surface (Ship) – Small-Caliber; Medium-Caliber; Large-Caliber • Missile Exercise (Surface-to-Surface) • Laser Targeting • Sinking Exercise

Table 3.0-22: Training Activities that Involve the Use of Surface Combatants (continued)

Training
Anti-Submarine Warfare
• Tracking Exercise/Torpedo Exercise – Surface • Tracking Exercise/Torpedo Exercise – Helicopter • Tracking Exercise/Torpedo Exercise – Maritime Patrol Aircraft • Multi-Strike Group Exercise • Rim of the Pacific Exercise • Integrated Anti-Submarine Warfare Course • Group Sail • Submarine Command Course • Anti-Submarine Warfare for Composite Training Unit Exercise • Anti-Submarine Warfare for Joint Task Force Exercise/Sustainment Exercise
Electronic Warfare
• Electronic Warfare Operations • Counter Targeting Chaff Exercise – Ship
Mine Warfare
• Mine Countermeasures Exercise – Ship Sonar • Mine Countermeasures Exercise – Surface • Airborne Mine Countermeasures – Towed Mine Neutralization • Mine Countermeasures – Mine Detection • Mine Countermeasures – Mine Neutralization Small-Caliber - and Medium-Caliber • Mine Countermeasures – Mine Neutralization – Remotely Operated Vehicle • Civilian Port Defense
Other Training Exercises
• Precision Anchoring • Offshore Petroleum Discharge System • Salvage Operations • Surface Ship Sonar Maintenance (in Operating Areas and Ports)

Table 3.0-23: Testing Activities that Involve the Use of Surface Combatants

Testing
Anti-Submarine Warfare
• Sonobuoy Lot Acceptance test
New Ship Construction
• Surface Combatant Sea Trials – Propulsion Testing • Surface Combatant Sea Trials – Gun Testing – Large-Caliber • Surface Combatant Sea Trials – Missile Testing • Surface Combatant Sea Trials – Decoy Testing • Surface Combatant Sea Trials – Surface Warfare Testing – Large-Caliber • Surface Combatant Sea Trials – Anti-Submarine Warfare Testing • Other Class Ship Sea Trial – Propulsion Testing • Other Class Ship Sea Trial – Gun Testing Small-Caliber • Anti-Submarine Warfare Mission Package Testing • Surface Warfare Mission Package Testing – Gun Testing Small-Caliber; Medium-Caliber; Large-Caliber • Surface Warfare Mission Package Testing – Missile/Rocket Testing • Mine Countermeasure Mission Package Testing • Post-Homeporting Testing (all classes)
Life Cycle Activities
• Ship Signature Testing • Surface Ship Sonar Testing/Maintenance (in Operating Areas and Ports) • Combat System Ship Qualification Trial – Air Defense • Combat System Ship Qualification Trial – Surface Warfare • Combat System Ship Qualification Trial – Undersea Warfare
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Missile Testing • Kinetic Energy Weapon Testing • Torpedo (Non-Explosive) Testing • Torpedo (Explosive) Testing • Countermeasure Testing • At-Sea Sonar Testing
Mine Warfare Testing
• Mine Detection and Classification • Mine Countermeasure/Neutralization Testing
Shipboard Protection Systems and Swimmer Defense Testing
• Shipboard Protection Systems Testing • Chemical/Biological Simulant Testing
Other
• Acoustic Communications Testing

Table 3.0-24: Training Activities That Involve the Use of Amphibious Warfare Ships

Training
Anti-Air Warfare
• Air Defense Exercises
Amphibious Warfare
• Expeditionary Fires Exercise/Supporting Arms Coordination Exercise • Amphibious Assault • Amphibious Raid • Amphibious Assault-Battalion Landing • Humanitarian Assistance Operations

Table 3.0-25: Testing Activities That Involve the Use of Amphibious Warfare Ships

Testing
New Ship Construction
• Other Class Ship Sea Trial – Propulsion Testing • Other Class Ship Sea Trial – Gun Testing Small-Caliber • Post-Homeporting Testing (All Classes)
Life Cycle Activities
• Combat System Ship Qualification Trial – Air Defense • Combat System Ship Qualification Trial – Surface Warfare
Mine Warfare Testing
• Mine Detection and Classification • Mine Countermeasure/Neutralization Testing

Table 3.0-26: Training Activities That Involve the Use of Support Craft

Training
Amphibious Warfare
• Naval Surface Fire Support Exercise – At Sea • Amphibious Assault • Amphibious Raid
Strike Warfare
• High-Speed Anti-Radiation Missile Exercise (Air - to - Surface)
Anti-Surface Warfare
• Maritime Security Operations • Gunnery Exercise Surface-to-Surface (Boat) – Small-Caliber; Medium-Caliber • Laser Targeting

Table 3.0-26: Training Activities That Involve the Use of Support Craft (continued)

Training
Anti-Submarine Warfare
• Tracking Exercise/Torpedo Exercise – Submarine • Tracking Exercise/Torpedo Exercise – Surface • Tracking Exercise/Torpedo Exercise – Maritime Patrol Aircraft
Mine Warfare
• Mine Neutralization/Explosive Ordnance Disposal • Mine Countermeasure – Mine Detection • Civilian Port Defense
Naval Special Warfare
• Underwater Demolition Multiple Charge – Mat Weave and Obstacle Loading • Underwater Demolition Qualification/Certification
Major Training Events
• Composite Training Unit Exercise
Other Training Exercises
• Small Boat Attack • Offshore Petroleum Discharge System • Elevated Causeway System • Salvage Operations

Table 3.0-27: Testing Activities That Involve the Use of Support Craft

Testing
New Ship Construction
• Surface Combatant Sea Trials – Missile Testing • Other Class Ship Sea Trial – Propulsion Testing • Other Class Ship Sea Trial – Gun Testing Small-Caliber • Post-Homeporting Testing (All Classes)
Life Cycle Activities
• Ship Signature Testing
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Torpedo (Non-Explosive) Testing • Torpedo (Explosive) Testing
Shipboard Protection Systems and Swimmer Defense Testing
• Pierside Integrated Swimmer Defense
Unmanned Vehicle Testing
• Unmanned Vehicle Development and Payload Testing

Table 3.0-27: Testing Activities That Involve the Use of Support Craft (continued)

Testing
Other Testing
• Special Warfare • Fixed System Underwater Communications • Fixed Autonomous Oceanographic Research and Meteorology and Oceanography • Fixed Intelligence, Surveillance, and Reconnaissance Sensor Systems • Fixed Sensor Systems Test

Table 3.0-28: Training Activities That Involve the Use of Submarines

Training
Anti-Surface Warfare
• Sinking Exercise
Anti-Submarine Warfare
• Tracking Exercise/Torpedo Exercise – Submarine • Tracking Exercise/Torpedo Exercise – Surface • Tracking Exercise/Torpedo Exercise – Maritime Patrol Aircraft • Tracking Exercise – Maritime Patrol Aircraft Extended Echo Ranging Sonobuoys • Anti-Submarine Warfare Tactical Development Exercise • Submarine Command Course
Mine Warfare
• Submarine Mine Exercise
Naval Special Warfare
• Personnel Insertion/Extraction-Submarine
Major Training Events
• Composite Training Unit Exercise • Joint Task Force Exercise/Sustainment Exercise • Rim of the Pacific Exercise • Multi-Strike Group Exercise • Integrated Anti-Submarine Warfare Course • Group Sail • Undersea Warfare Exercise • Ship Anti-Submarine Warfare Readiness and Evaluation Measuring
Other Training Exercises
• Submarine Navigational • Submarine Under Ice Certification • Submarine Sonar Maintenance (in Operating Areas and Ports)

Table 3.0-29: Testing Activities That Involve the Use of Submarines

Testing
Life Cycle Activities
• Submarine Sonar Testing/Maintenance (in Operating Areas and Ports) • Ship Signature Testing
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Anti-submarine Warfare Tracking Test – Helicopter • Anti-submarine Warfare Tracking Test – Maritime Patrol Aircraft • Missile Testing • Electronic Warfare Testing • Torpedo (Non-Explosive) Testing • Torpedo (Explosive) Testing • At-Sea Sonar Testing
Unmanned Vehicle Testing
• Underwater Deployed Unmanned Aerial System Testing
Other
• Special Warfare • Acoustic Communications Testing

Table 3.0-30 provides the estimated number of events that include the use of vessels for each alternative. The location and hours of Navy vessel usage for testing and training 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 the last decade and are not expected to change in the foreseeable future.

Table 3.0-30: Annual Number and Location of Events Including Vessel Movement

Activity Area	Training			Testing		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
HRC	846	1,856	1,856	4,587	4,957	5,677
SOCAL	6,732	7,287	7,287	4,761	5,196	5,729
SSTC	268	268	268	71	78	87
Transit Corridor	0	79	79	0	2	3
Total	**7,846**	**9,490**	**9,490**	**9,419**	**10,233**	**11,496**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex), SSTC = Silver Strand Training 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. The difference between the No Action Alternative and Alternatives 1 and 2 includes an expansion of the Study Area and an increase in the number of activities. Because multiple activities usually occur from the same vessel, the increased activities would not necessarily result in an increase in vessel use or transit. The concentration of use in and the manner in which the Navy uses vessels to accomplish its testing and training 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.

3.0.5.3.3.2 In-Water Devices

In-water devices as discussed in this analysis are unmanned vehicles, such as remotely operated vehicles, unmanned surface vehicles, unmanned undersea vehicles, and towed devices. These devices are self-propelled and unmanned or towed through the water from a variety of platforms, including helicopters and surface ships. In-water devices are generally smaller than most Navy vessels ranging from several inches to about 15 m. See Table 3.0-31 for a range of in-water devises used.

Table 3.0-31: Representative Types, Sizes, and Speeds of In-water Devices

Type	Example(s)	Length	Typical Operating Speed
Towed Device	Minehunting SONAR AQS Systems; Improved Surface Tow Target; Towed SONAR System; MK-103, MK-104 and MK-105 Minesweeping Systems; OASIS, Orion, Shallow Water Intermediate Search System, Towed Pinger Locator 30	< 10 m	10–40 knots
Unmanned Surface Vehicle	MK-33 SEPTAR Drone Boat, QST-35A Seaborne Powered Target, Ship Deployable Seaborne Target, Small Waterplane Area Twin Hull, Unmanned Influence Sweep System (UISS)	< 15 m	Variable, up to 50+ knots
Unmanned Undersea Vehicle	Acoustic Mine Targeting System, Airborne Mine Neutralization System (AMNS), AN/ASQ Systems, Archerfish Common Neutralizer, Crawlers, CURV 21, Deep Drone 8000, Deep Submergence Rescue Vehicle, Gliders, EMATTs, Light and Heavy Weight Torpedoes, Large Diameter Unmanned Underwater Vehicle, Magnum ROV, Manned Portables, MINIROVs, MK 30 ASW Targets, RMMV, Remote Minehunting System (RMS), Unmanned Influence Sweep System (UISS)	< 15 m	1–15 knots

Notes: EMATT = Expendable Mobile Anti-Submarine Warfare Training Target, ROV = Remotely Operated Vehicle, MINIROV = miniature ROV , RMMV = Remote Multi-Mission Vehicle

These devices can operate anywhere from the water surface to the benthic zone. Certain 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 undersurface vehicles) or are closely monitored by observers manning the towing platform (e.g. most towed devices). Because of their size and potential operating speed, in-water devices that operate in a manner with the potential to strike living marine resources are the Unmanned Surface Vehicles.

Training and testing activities that employ towed in-water devices are listed in Table 3.0-32 through Table 3.0-37.

Table 3.0-32: Training Activities That Involve the Use of Towed Devices

Training
Anti-Surface Warfare
• Gunnery Exercise Surface-to-Surface (Ship) – Small-Caliber; Medium-Caliber • Gunnery Exercise Surface-to-Surface (Boat) – Medium-Caliber • Missile Exercise (Surface-to-Surface) • Gunnery Exercise (Air-to-Surface) – Small-Caliber; Medium-Caliber • Missile Exercise (Air-to-Surface) – Rocket • Missile Exercise (Air-to-Surface)
Anti-Submarine Warfare
• Integrated Anti-Submarine Warfare Course • Group Sail
Mine Warfare
• Mine Countermeasures Exercise – Ship Sonar • Mine Countermeasure – Towed Mine Neutralization • Mine Countermeasure – Mine Detection • Civilian Port Defense

Table 3.0-33: Testing Activities That Involve the Use of Towed Devices

Testing
Mine Warfare
• Airborne Towed Minesweeping Test • Airborne Towed Minehunting Sonar Test
New Ship Construction
• Mine Countermeasure Mission Package Testing
Life Cycle Activities
• Combat System Ship Qualification Trial – Surface Warfare
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Countermeasure Testing

Table 3.0-34: Training Activities That Involve the Use of Unmanned Surface Vehicles

Training
Amphibious Warfare
• Amphibious Raid
Anti-Surface Warfare
• Maritime Security Operations • Gunnery Exercise Surface-to-Surface (Ship) – Small-Caliber; Medium-Caliber; Large-Caliber • Missile Exercise (Surface-to-Surface) • Gunnery Exercise (Air-to-Surface) – Small-Caliber; Medium-Caliber • Missile Exercise (Air-to-Surface)

Table 3.0-34: Training Activities That Involve the Use of Unmanned Surface Vehicles (continued)

Training
Mine Warfare
• Mine Countermeasure – Towed Mine Neutralization • Mine Countermeasure – Mine Detection • Civilian Port Defense
Major Range Events
• Composite Training Unit Exercise

Table 3.0-35: Testing Activities That Involve the Use of Unmanned Surface Vehicles

Testing
New Ship Construction
• Surface Combatant Sea Trials – Surface Warfare Testing – Large-Caliber
Life Cycle Activities
• Combat System Ship Qualification Trial – Anti-Surface Warfare
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Missile Testing
Shipboard Protection Systems and Swimmer Defense Testing
• Shipboard Protection Systems Testing
Unmanned Vehicle Testing
• Unmanned Vehicle Development and Payload Testing

Table 3.0-36: Training Activities That Involve the Use of Unmanned Underwater Vehicles

Training
Anti-Surface Warfare
• Sinking Exercise
Anti-Submarine Warfare
• Tracking Exercise/Torpedo Exercise – Submarine • Tracking Exercise/Torpedo Exercise – Surface • Tracking Exercise/Torpedo Exercise – Maritime Patrol Aircraft • Integrated Anti-Submarine Warfare Course • Group Sail • Submarine Command Course Operations • Anti-Submarine Warfare for Composite Training Unit Exercise • Anti-Submarine Warfare for Joint Task Force Exercise/Sustainment Exercise
Mine Warfare
• Mine Countermeasures Exercise – Ship Sonar • Mine Countermeasure – Towed Mine Neutralization • Mine Countermeasure – Mine Detection • Mine Countermeasures – Mine Neutralization – Remotely Operated Vehicle • Civilian Port Defense

Table 3.0-37: Testing Activities That Involve the Use of Unmanned Underwater Vehicles

Testing
Anti-Submarine Warfare
• Anti-Submarine Warfare Torpedo Test • Anti-Submarine Tracking Test – Helicopter • Anti-Submarine Warfare Tracking Test – Maritime Patrol Aircraft
Mine Warfare
• Airborne Mine Neutralization Systems Test – ASQ-235 • Mine Countermeasure/Neutralization Testing
New Ship Construction
• Surface Combatant Sea Trials – Anti-Submarine Warfare Testing • Anti-Submarine Warfare Mission Package Testing • Mine Countermeasure Mission Package Testing
Life Cycle Activities
• Combat System Ship Qualification Trial – Undersea Warfare
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Torpedo (Non-Explosive) Testing • Torpedo (Explosive) Testing • Countermeasure Testing – Surface Ship Defense System Testing
Unmanned Vehicle Testing
• Underwater Deployed Unmanned Aerial System Testing

Table 3.0-38 provides estimates of relative in-water device use and location, for each of the alternatives. These are based on the estimated number of events that include the use of in-water devices for each alternative. While these estimates provide the average distribution of in-water devices, actual locations and hours of Navy in-water device usage are dependent upon military training and testing requirements, deployment schedules, annual budgets and other unpredictable factors.

Table 3.0-38: Annual Number and Location of Events Including In-Water Devices

Activity Area	Training			Testing		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
HRC	1,065	1,625	1,625	43	240	266
SOCAL	2,627	3,061	3,061	210	517	581
SSTC	308	308	308	53	58	65
Total	**4,000**	**5,055**	**5,055**	**306**	**815**	**912**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex), SSTC = Silver Strand Training Complex

3.0.5.3.3.3 Military Expended Materials

Military expended materials include: (1) all sizes of non-explosive practice munitions; (2) fragments from high explosive munitions; and (3) expended materials other than ordnance, such as sonobuoys, ship hulks, expendable targets and unrecovered aircraft stores (fuel tanks, carriages, dispensers, racks, or similar types of support systems on aircraft).

While disturbance or strike from any material as it falls through the water column is possible, it is not likely because the objects will slow in velocity as it sinks toward the bottom and can be avoided by highly mobile organisms. 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 (i.e., invertebrates and vegetation).

Training and testing activities that involve the use of non-explosive practice munitions (small-, medium-, and large-caliber missiles, rockets, bombs, torpedoes, and neutralizers), fragments from high explosives, and materials other than munitions (flares, chaff, sonobuoys, parachutes, aircraft stores and ballast, and targets) are detailed in Table 3.0-39 through Table 3.0-64. Table 3.0-65 through Table 3.0-67 provide the number and location of munitions and targets.

Table 3.0-39: Training Activities That Expend Non-Explosive Small-Caliber Projectiles

Training
Strike Warfare
• Gunnery Exercise (Air-to-Ground)
Anti-Surface Warfare
• Gunnery Exercise Surface-to-Surface (Ship) – Small-Caliber • Gunnery Exercise Surface-to-Surface (Boat) – Small-Caliber • Gunnery Exercise Air-to-Surface – Small-Caliber
Mine Warfare
• Mine Countermeasures – Mine Neutralization – Small-Caliber and Medium-Caliber
Other
• Small Boat Attack

Table 3.0-40: Testing Activities That Expend Non-Explosive Small-Caliber Projectiles

Testing
New Ship Construction
• Other Class Ship Sea Trials – Gun Testing – Small-Caliber • Surface Warfare Mission Package Testing – Gun Testing – Small-Caliber
Shipboard Protection Systems and Swimmer Defense Testing
• Shipboard Protection Systems Testing

Table 3.0-41: Training Activities That Expend Non-Explosive Medium-Caliber Projectiles

Training
Anti-Air Warfare
• Gunnery Exercise (Air-to-Air) – Medium-Caliber • Gunnery Exercise (Surface-to-Air) – Medium-Caliber
Strike Warfare
• Gunnery Exercise (Air-to-Ground)

Table 3.0-41: Training Activities That Expend Non-Explosive Medium-Caliber Projectiles (continued)

Training
Anti-Surface Warfare
• Gunnery Exercise Surface-to-Surface (Ship) – Medium-Caliber • Gunnery Exercise Surface-to-Surface (Boat) – Medium-Caliber • Gunnery Exercise (Air-to-Surface) – Medium-Caliber • Sinking Exercise
Mine Warfare
• Mine Countermeasure – Mine Neutralization

Table 3.0-42: Testing Activities That Expend Non-Explosive Medium-Caliber Projectiles

Testing
Anti-Air Warfare
• Air Platform Weapons Integration Test
Anti-Surface Warfare
• Air-to-Surface Gunnery Test – Medium-Caliber
Mine Warfare
• Airborne Projectile-Based Mine Clearance System
New Ship Construction
• Surface Warfare Mission Package Testing – Gun Testing – Medium-Caliber
Life Cycle Activities
• Combat System Ship Qualification Trial – Air Defense • Combat System Ship Qualification Trial – Surface Warfare

Table 3.0-43: Training Activities That Expend Non-Explosive Large-Caliber Projectiles

Training
Anti-Air Warfare
• Gunnery Exercise (Surface-to-Air) – Large-Caliber
Amphibious Warfare
• Naval Surface Fire Support Exercise – At Sea • Expeditionary Fires Exercise/Supporting Arms Coordination Exercise
Anti-Surface Warfare
• Gunnery Exercise Surface-to-Surface (Ship) – Large-Caliber • Sinking Exercise

Table 3.0-44: Testing Activities That Expend Non-Explosive Large-Caliber Projectiles

Testing
New Ship Construction
• Surface Combatant Sea Trials – Gun Testing – Large-Caliber • Surface Combatant Sea Trials – Surface Warfare Testing – Large-Caliber • Surface Warfare Mission Package Testing – Gun Testing, Large-Caliber
Life Cycle Activities
• Combat System Ship Qualification Trial – Air Defense • Combat System Ship Qualification Trial – Surface Warfare
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Kinetic Energy Weapon Testing

Table 3.0-45: Training Activities That Expend Non-Explosive Bombs

Training
Strike Warfare
• Bombing Exercise (Air-to-Ground)
Anti-Surface Warfare
• Bombing Exercise (Air-to-Surface) • Sinking Exercise

Table 3.0-46: Testing Activities That Expend Non-Explosive Bombs

Testing
NONE

Table 3.0-47: Training Activities That Expend Non-Explosive Missiles or Rockets

Training
Anti-Air Warfare
• Missile Exercise (Air-to-Air)
Anti-Surface Warfare
• Missile Exercise (Surface-to-Surface) • Missile Exercise (Air-to-Surface) – Rocket • Sinking Exercise

Table 3.0-48: Testing Activities That Expend Non-Explosive Missiles or Rockets

Testing
Anti-Air Warfare
• Air Platform Weapons Integration Test
Anti-Surface Warfare
• Air-to-Surface Missile Test • Rocket Test

Table 3.0-48: Testing Activities That Expend Non-Explosive Missiles or Rockets (continued)

Testing
New Ship Construction
• Surface Combatant Sea Trials – Missile Testing • Surface Warfare Mission Package Testing – Missile/Rocket Testing
Life Cycle Activities
• Combat System Ship Qualification Trial – Air Defense • Combat System Ship Qualification Trial – Surface Warfare
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Missile Testing

Table 3.0-49: Training Activities That Expend Aircraft Stores or Ballast

Training
Anti-Submarine Warfare
• Tracking Exercise/Torpedo Exercise – Submarine • Tracking Exercise/Torpedo Exercise – Surface • Tracking Exercise/Torpedo Exercise – Maritime Patrol Aircraft • Tracking Exercise/Torpedo Exercise – Helicopter • Submarine Command Course Operations

Table 3.0-50: Testing Activities That Expend Aircraft Stores or Ballast

Testing
Anti-Air Warfare
• Air Platform/Vehicle Test
Anti-Surface Warfare
• Rocket Test
Anti-Submarine Warfare
• Anti-Submarine Warfare Torpedo Test
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Torpedo (Non-Explosive) Testing
Unmanned Vehicle Testing
• Underwater Deployed Unmanned Aerial System Testing

Table 3.0-51: Training Activities That Expend Non-Explosive Sonobuoys

Training
Anti-Submarine Warfare
• Tracking Exercise/Torpedo Exercise – Helicopter • Tracking Exercise/Torpedo Exercise – Maritime Patrol Aircraft • Tracking Exercise – Maritime Patrol Advanced Extended Echo Ranging Sonobuoys • Integrated Anti-Submarine Warfare Course • Group Sail • Anti-Submarine Warfare for Composite Training Unit Exercise • Anti-Submarine Warfare for Joint Task Force Exercise/Sustainment Exercise

Table 3.0-52: Testing Activities That Expend Non-Explosive Sonobuoys

Testing
Anti-Submarine Warfare
• Anti-Submarine Warfare Torpedo Test • Sonobuoy Lot Acceptance Test • Anti-Submarine Tracking Test – Helicopter • Anti-Submarine Warfare Tracking Test – Maritime Patrol Aircraft
New Ship Construction
• Surface Combatant Sea Trials – Anti-Submarine Warfare Testing • Anti-Submarine Warfare Mission Package Testing
Life Cycle Activities
• Combat System Ship Qualification Trial – Undersea Warfare
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Torpedo (Non-Explosive) Testing • Torpedo (Explosive) Testing

Table 3.0-53: Training Activities That Expend Parachutes

Training
Anti-Air Warfare
• Missile Exercise (Air-to-Air)
Anti-Submarine Warfare
• Tracking Exercise/Torpedo Exercise – Maritime Patrol Aircraft • Tracking Exercise – Maritime Patrol Aircraft Extended Echo Ranging Sonobuoys • Tracking Exercise/Torpedo Exercise-Helicopter

Table 3.0-53: Training Activities That Expend Parachutes (continued)

Training
Major Training Events
• Anti-Submarine Warfare for Composite Training Unit Exercise • Anti-Submarine Warfare for Joint Task Force Exercise/Sustainment Exercise • Rim of the Pacific Exercise • Multi-Strike Group Exercise • Integrated Anti-Submarine Warfare Course • Group Sail • Undersea Warfare Exercise • Ship Anti-Submarine Warfare Readiness and Evaluation Measuring

Table 3.0-54: Testing Activities That Expend Parachutes

Testing
Anti-Submarine Warfare
• Anti-Submarine Warfare Torpedo Test • Sonobuoy Lot Acceptance test • Anti-Submarine Tracking Test – Helicopter • Anti-Submarine Warfare Tracking Test – Maritime Patrol Aircraft
New Ship Construction
• Anti-Submarine Warfare Mission Package Testing • Surface Combatant Sea Trials – Anti-Submarine Warfare Testing
Life Cycle Activities
• Combat System Ship Qualification Trial – Undersea Warfare
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Torpedo (Non-Explosive) Testing • Torpedo (Explosive) Testing • Countermeasure Testing

Table 3.0-55: Training Activities That Expend Chaff

Training
Electronic Warfare
• Counter Targeting Chaff Exercise – Ship • Counter Targeting Chaff Exercise – Aircraft

Table 3.0-56: Testing Activities That Expend Chaff

Testing
Anti-Air Warfare
• Air Combat Maneuver Test
New Ship Construction
• Surface Combatant Sea Trials – Decoy Testing
Lifecycle Activities
• Combat System Ship Qualification Trial – Air Defense

Table 3.0-57: Training Activities That Expend Flares

Training
Anti-Air Warfare
• Missile Exercise (Air-to-Air)
Electronic Warfare
• Counter Targeting Flare Exercise

Table 3.0-58: Testing Activities That Expend Flares

Testing
• Air Platform/Vehicle Test

Table 3.0-59: Training Activities That Expend Fragments from High-Explosive Munitions

Training
Anti-Air Warfare
• Gunnery Exercise (Surface-to-Air) – Large-Caliber • Missile Exercise (Surface-to-Air) • Missile Exercise (Air-to-Air) • Missile Exercise – Man-portable Air Defense System
Amphibious Warfare
• Naval Surface Fire Support Exercise – At Sea
Anti-Surface Warfare
• Gunnery Exercise Surface-to-Surface (Ship) – Medium-Caliber • Gunnery Exercise Surface-to-Surface (Ship) – Large-Caliber • Gunnery Exercise Surface-to-Surface (Boat) – Medium-Caliber • Gunnery Exercise (Air-to-Surface) – Medium-Caliber • Missile Exercise (Air-to-Surface) – Rocket • Missile Exercise (Air-to-Surface) • Bombing Exercise (Air-to-Surface) • Sinking Exercise
Anti-Submarine Warfare
• Tracking Exercise – Maritime Patrol Aircraft Extended Echo Ranging Sonobuoys • Anti-Submarine Warfare for Composite Training Unit Exercise • Anti-Submarine Warfare for Joint Task Force Exercise/Sustainment Exercise

Table 3.0-59: Training Activities That Expend Fragments from High-Explosives (continued)

Training
Mine Warfare
• Mine Neutralization/Explosive Ordnance Disposal • Mine Countermeasure – Mine Neutralization – Remotely Operated Vehicles • Marine Mammal System • Civilian Port Defense

Table 3.0-60: Testing Activities That Expend Fragments from High-Explosive Munitions

Testing
Anti-Surface Warfare
• Air-to-Surface Missile Test • Air-to-Surface Gunnery Test – Medium-Caliber • Rocket Test
Anti-Submarine Warfare
• Sonobuoy Lot Acceptance Test • Anti-Submarine Tracking Test – Helicopter • Anti-Submarine Warfare Tracking Test – Maritime Patrol Aircraft
Mine Warfare
• Airborne Mine Neutralization Systems Test – ASQ-235 • Airborne Projectile-Based Mine Clearance System
New Ship Construction
• Surface Combatant Sea Trials – Missile Testing • Surface Warfare Mission Package Testing – Missile/Rocket Testing • Surface Warfare Mission Package Testing – Gun Testing, Medium-Caliber • Surface Warfare Mission Package Testing – Gun Testing, Large-Caliber • Mine Countermeasure Mission Package Testing
Life Cycle Activities
• Combat System Ship Qualification Trial – Air Defense • Combat System Ship Qualification Trial – Surface Warfare
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Torpedo (Explosive) Testing • Countermeasure Testing
Mine Warfare
• Mine Countermeasure/Neutralization Testing
Other Testing – Naval Sea Systems Command
• At-Sea Explosives Testing

Table 3.0-61: Training Activities That Expend Fragments from Targets

Training
Anti-Air Warfare
• Missile Exercise (Air-to-Air) • Gunnery Exercise (Surface-to-Air) – Large-Caliber • Missile Exercise – Man-portable Air Defense System
Anti-Surface Warfare
• Gunnery Exercise (Surface to-Surface) – Ship Small-Caliber, Medium-Caliber, and Large-Caliber • Gunnery Exercise (Surface-to-Surface) – Boat Small- and Medium-Caliber • Missile Exercise (Surface-to-Surface) • Gunnery Exercise (Air-to-Surface) – Small-Caliber; Medium-Caliber • Missile Exercise (Air-to-Surface) – Rocket • Missile Exercise (Air-to-Surface) • Bombing Exercise (Air-to-Surface)
Mine Warfare
• Mine Neutralization – Explosive Ordnance Disposal • Mine Countermeasure – Mine Neutralization – Remotely Operated Vehicle
Major Training Events
• Composite Training Unit Exercise • Integrated Anti-Submarine Warfare Course • Rim of the Pacific Exercise • Multi-Strike Group Exercise • Integrated Anti-Submarine Warfare Course • Group Sail • Undersea Warfare Exercise • Ship Anti-Submarine Warfare Readiness and Evaluation Measuring

Table 3.0-62: Testing Activities That Expend Fragments from Targets

Testing
Anti-Surface Warfare
• Air-to-Surface Missile Test • Air-to-Surface Gunnery Test – Medium-Caliber • Rocket Test
Mine Warfare
• Airborne Mine Neutralization Systems Test – AQS-235 • Airborne Projectile-Based Mine Clearance System
New Ship Construction
• Surface Combatant Sea Trials – Surface Warfare Testing – Large-Caliber • Mine Countermeasure Mission Package Testing

Table 3.0-62: Testing Activities That Expend Fragments from Targets (continued)

Testing
Life Cycle Activities
• Combat System Ship Qualification Trial – Air Defense • Combat System Ship Qualification Trial – Surface Warfare
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Torpedo (Explosive) Testing • Kinetic Energy Weapon Testing
Mine Warfare Testing
• Mine Countermeasure/Neutralization Testing
Shipboard Protection Systems and Swimmer Defense Testing
• Shipboard Protection Systems Testing

Table 3.0-63: Training Activities That Expend Torpedo Accessories

Training
Anti-Surface Warfare
• Sinking Exercise
Anti-Submarine Warfare
• Tracking Exercise/Torpedo Exercise – Submarine • Tracking Exercise/Torpedo Exercise – Surface • Tracking Exercise/Torpedo Exercise – Helicopter • Tracking Exercise/Torpedo Exercise – Maritime Patrol Aircraft • Submarine Command Course Operations

Table 3.0-64: Testing Activities That Expend Torpedo Accessories

Testing
Anti-Submarine Warfare
• Anti-Submarine Warfare Torpedo Test
New Ship Construction
• Anti-Submarine Warfare Mission Package Testing
Life Cycle Activities
• Combat System Ship Qualification Trial – Undersea Warfare
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Torpedo (Non-explosive) Testing • Torpedo (Explosive) Testing • Countermeasure Testing

Table 3.0-65: Annual Number and Location of Non-Explosive Practice Munitions Expended

Location	Training			Testing		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
Mine Neutralization System Neutralizers						
HRC	0	0	0	0	48	64
SOCAL	360	360	360	100	348	394
Total	**360**	**360**	**360**	**100**	**396**	**458**
Torpedoes[1]						
HRC	530	625	625	186	382	591
SOCAL	398	509	509	260	460	640
Total	**928**	**1,134**	**1,134**	**446**	**842**	**1,231**
Bombs						
HRC	477	399	399	0	0	0
SOCAL	640	1,120	1,120	0	0	0
Transit Corridor	0	90	90	0	0	0
Total	**1,117**	**1,609**	**1,609**	**0**	**0**	**0**
Rockets						
SOCAL	0	0	0	15	696	781
Total	**0**	**0**	**0**	**15**	**696**	**781**
Missiles						
HRC	60	64	64	4	68	70
SOCAL	26	30	30	74	138	148
Total	**86**	**94**	**94**	**78**	**206**	**218**
Large-Caliber Projectiles						
HRC	7,500	1,464	1,464	0	9,182	9,592
SOCAL	16,900	5,596	5,596	0	2,897	3,107
Transit Corridor	0	380	380	0	0	0
Total	**24,400**	**7,440**	**7,440**	**0**	**12,079**	**12,699**
Medium-Caliber Projectiles						
HRC	97,600	195,360	195,360	0	26,800	27,150
SOCAL	281,000	435,160	417,640	6,500	57,100	61,480
Transit Corridor	0	6,080	6,080	0	0	0
Total	**378,600**	**636,600**	**636,600**	**6,500**	**83,900**	**88,630**
Small-Caliber Projectiles						
HRC	68,300	422,000	422,000	0	6,600	8,250
SOCAL	913,000	2,559,800	2,559,800	0	13,600	15,550
Transit Corridor	0	84,000	84,000	0	0	0
Total	**981,300**	**3,065,800**	**3,065,800**	**0**	**20,200**	**23,800**

[1]All exercise torpedoes listed here are recovered.

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex), SSTC = Silver Strand Training Complex

Table 3.0-65: Annual Number and Location of Non-Explosive Practice Munitions Expended (continued)

Location	Training			Testing		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
Sonobuoys						
HRC	25,000	24,500	24,500	1,817	4,032	4,343
SOCAL	17,250	26,800	26,800	5,322	8,047	8,896
Transit Corridor	0	200	200	0	0	0
Total	**42,250**	**51,500**	**51,500**	**7,139**	**12,079**	**13,239**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex), SSTC = Silver Strand Training Complex

Table 3.0-66: Annual Number and Location of High-Explosives that May Result in Fragments

Location	Training			Testing		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
Torpedoes						
HRC	6	6	6	8	26	29
SOCAL	2	2	2	8	8	8
Total	**8**	**8**	**8**	**16**	**34**	**37**
Sonobuoys						
HRC	0	480	480	314	408	500
SOCAL	0	120	120	2,652	2,760	2,892
Total	**0**	**600**	**600**	**2,996**	**3,168**	**3,392**
Neutralizers						
SOCAL	0	0	0	40	40	44
Total	**0**	**0**	**0**	**40**	**40**	**44**
Rockets						
HRC	0	760	760	0	0	0
SOCAL	0	3,800	3,800	0	284	297
Total	**0**	**4,560**	**4,560**	**0**	**284**	**297**
Anti-Swimmer Grenades						
HRC	0	100	100	0	0	0
SOCAL	0	140	140	0	0	0
Total	**0**	**240**	**240**	**0**	**0**	**0**
Missiles						
HRC	160	146	146	4	54	56
SOCAL	142	330	330	29	64	70
Total	**302**	**476**	**476**	**33**	**118**	**126**

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

Table 3.0-66: Annual Number and Location of High-Explosives that May Result in Fragments (continued)

Location	Training			Testing		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
Large-Caliber Projectiles						
HRC	11,200	1,894	1,894	0	2,690	3,680
SOCAL	16,400	4,244	4,244	0	3,470	4,460
Transit Corridor	0	20	20	0	0	0
Total	**27,600**	**6,158**	**6,158**	**0**	**6,160**	**8,140**
Medium-Caliber Projectiles						
HRC	3,100	6,640	6,640	0	1,400	1,750
SOCAL	15,000	13,920	13,920	2,500	16,400	18,250
Transit Corridor	0	320	320	0	0	0
Total	**18,100**	**20,880**	**20,880**	**2,500**	**17,800**	**20,000**

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

Table 3.0-67: Annual Number and Location of Targets Expended

Location	Training			Testing		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
Sub-surface Targets						
HRC	370	405	405	32	165	177
SOCAL	670	550	550	24	225	243
Transit Corridor	0	10	10	0	0	0
Total	**1,040**	**965**	**965**	**56**	**390**	**420**
Surface Targets						
HRC	200	450	450	8	40	43
SOCAL	400	1,150	1,150	109	178	197
SSTC	0	0	0	0	0	0
Transit Corridor	0	65	65	0	0	0
Total	**600**	**1,665**	**1,665**	**117**	**218**	**240**
Air Targets						
HRC	24	26	26	0	41	52
SOCAL	45	45	45	0	13	24
Total	**69**	**71**	**71**	**0**	**54**	**76**
Mine Shapes						
HRC	336	384	384	0	0	0
SOCAL	216	216	216	0	0	0
Total	**552**	**600**	**600**	**0**	**0**	**0**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex), SSTC = Silver Strand Training Complex

Table 3.0-67 Annual Number and Location of Targets Expended (continued)

Location	Training			Testing		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
Ship Hulk						
HRC	6	6	6	0	0	0
SOCAL	2	2	2	0	0	0
Total	8	8	8	0	0	0

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex), SSTC = Silver Strand Training Complex

3.0.5.3.3.4 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, anchors, bottom placed instruments, and robotic vehicles referred to as “crawlers.” Seafloor devices are either stationary or move very slowly along the bottom and do not pose a threat to highly mobile organisms. The effect of devices on the bottom will be discussed as an alteration of the bottom substrate and associated living resources (i.e., invertebrates and vegetation).

Training and testing activities that include the deployment of sea floor devices are listed in Table 3.0-68 and Table 3.0-69.

Table 3.0-68: Training Activities That Deploy Sea Floor Devices

Training
Mine Warfare
• Mine Countermeasures Exercise – Ship Sonar • Mine Neutralization/Explosive Ordnance Disposal • Mine Countermeasure – Towed Mine Neutralization • Mine Countermeasure – Mine Detection • Mine Countermeasure – Mine Neutralization, Small-Caliber and Medium-Caliber • Mine Countermeasure – Mine Neutralization – Remotely Operated Vehicles • Civilian Port Defense
Other Training Exercises
• Precision Anchoring

Table 3.0-69: Testing Activities That Deploy Sea Floor Devices

Testing
Mine Warfare
• Airborne Mine Neutralization Systems Test – ASQ-235 • Airborne Projectile-Based Mine Clearance System • Airborne Towed Minesweeping Test • Mine Laying Test
Shipboard Protection Systems and Swimmer Defense Testing
• Pierside Integrated Swimmer Defense
Unmanned Vehicle Testing
• Unmanned Vehicle Development and Payload Testing

The location and number of events including seafloor devices are summarized in Table 3.0-70.

Table 3.0-70: Annual Number and Location of Events Including Seafloor Devices

Activity Area	Training			Testing		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
HRC	133	73	73	0	15	17
SOCAL	1,317	1,241	1,241	35	59	65
SSTC	587	587	587	0	0	0
Transit Corridor	0	0	0	0	0	0
Total	**2,037**	**1,901**	**1,901**	**35**	**74**	**82**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex), SSTC = Silver Strand Training Complex

3.0.5.3.3.5 Aircraft Strikes

Aircraft involved in Navy training and testing activities are separated into three categories: (1) fixed-wing aircraft, (2) rotary-wing aircraft, and (3) 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 generally helicopters, such as MH-60. Unmanned aerial systems include a variety of platforms, including but not limited to, the Small Tactical Unmanned Aerial System – Tier II, Broad Area Maritime Surveillance unmanned aircraft, Fire Scout Vertical Take-off and Landing Unmanned Aerial Vehicle, and the Unmanned Combat Air System. Aircraft strikes are only applicable to birds.

Table 3.0-71 through Table 3.0-76 list the training and testing activities that include the use of various types of aircraft.

Table 3.0-71: Training Activities That Include Fixed-Wing Aircraft

Training
Anti-Air Warfare
• Air Combat Maneuver • Air Defense Exercises • Gunnery Exercise (Air-to-Air) – Large-Caliber and Medium-Caliber • Missile Exercise (Air-to-Air)
Amphibious Warfare
• Humanitarian Assistance Operations • Expeditionary Fires Exercise/Supporting Arms Coordination Exercise
Strike Warfare
• Bombing Exercise (Air-to-Ground)
Anti-Surface Warfare
• Gunnery Exercise (Air-to-Surface) – Medium-Caliber • Missile Exercise (Air-to-Surface) – Rocket • Missile Exercise (Air-to-Surface) • Bombing Exercise (Air-to-Surface) • Laser Targeting • Sinking Exercise
Anti-Submarine Warfare
• Tracking Exercise/Torpedo Exercise – Maritime Patrol Aircraft • Tracking Exercise – Maritime Patrol Aircraft Extended Echo Ranging Sonobuoys • Anti-Submarine Warfare Tactical Development Exercise • Integrated Anti-Submarine Warfare Course • Anti-Submarine Warfare for Joint Task Force Exercise/Sustainment Exercise
Electronic Warfare
• Electronic Warfare Operations • Counter Targeting – Flare Exercise • Counter Targeting Chaff Exercise – Aircraft
Mine Warfare
• Mine Laying
Naval Special Warfare
• Personnel Insertion/Extraction – Non-submarine
Major Training Events
• Composite Training Unit Exercise • Integrated Anti-Submarine Warfare Course • Rim of the Pacific Exercise • Multi-Strike Group Exercise • Integrated Anti-Submarine Warfare Course • Undersea Warfare Exercise • Ship Anti-Submarine Warfare Readiness and Evaluation Measuring

Table 3.0-72: Testing Activities That Include Fixed-Wing Aircraft

Testing
Anti-Air Warfare
• All Activities
Anti-Surface Warfare
• Air-to-Surface Missile Test • Air-to-Surface Gunnery Test – Medium-Caliber • Rocket Test • Air-to-Surface Bombing Test • Laser Targeting
Electronic Warfare
• Electronic Systems Evaluation
Anti-Submarine Warfare
• Anti-Submarine Warfare Torpedo Test • Sonobuoy Lot Acceptance Test • Anti-Submarine Warfare Tracking Test – Maritime Patrol Aircraft
Other Testing – Naval Air Systems Command
• Test and Evaluation Catapult Launch • Air Platform Shipboard Integrate Test • Shipboard Electronic Systems Evaluation
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Torpedo (Non-Explosive) Testing • Torpedo (Explosive) Testing
Shipboard Protection Systems and Swimmer Defense Testing
• Chemical/Biological Simulant Testing

Table 3.0-73: Training Activities That Include Rotary-Wing Aircraft

Training
Amphibious Warfare
• Expeditionary Fires Exercise/Supporting Arms Coordination Exercise • Amphibious Assault • Humanitarian Assistance Operations
Strike Warfare
• Gunnery Exercise (Air-to-Ground)
Anti-Surface Warfare
• Maritime Security Operations • Gunnery Exercise (Air-to-Surface) – Small-Caliber • Gunnery Exercise (Air-to-Surface) – Medium-Caliber • Missile Exercise (Air-to-Surface) – Rocket • Missile Exercise (Air-to-Surface) • Laser Targeting • Sinking Exercise

Table 3.0-73: Training Activities That Include Rotary-Wing Aircraft (continued)

Training
Anti-Submarine Warfare
• Tracking Exercise/Torpedo Exercise – Helicopter • Kilo Dip
Electronic Warfare
• Electronic Warfare Operations • Counter Targeting – Flare Exercise • Counter Targeting Chaff Exercise – Aircraft
Mine Warfare
• Mine Neutralization/Explosive Ordnance Disposal • Mine Countermeasure – Towed Mine Neutralization • Mine Countermeasure – Mine Detection • Mine Countermeasures – Mine Neutralization • Mine Countermeasures – Mine Neutralization – Remotely Operated Vehicles • Civilian Port Defense
Naval Special Warfare
• Personnel Insertion/Extraction – Non-submarine
Major Training Events
• Integrated Anti-Submarine Warfare Course • Group Sail • Composite Training Unit Exercise • Joint Task Force Exercise/Sustainment Exercise • Multi-Strike Group Exercise • Rim of the Pacific Exercise • Undersea Warfare Exercise • Ship Anti-Submarine Warfare Readiness and Evaluation Measuring

Table 3.0-74: Testing Activities That Include Rotary-Wing Aircraft

Testing
Anti-Air Warfare
• Air Platform/Vehicle Test • Air Platform Weapons Integration Test • Intelligence, Surveillance, and Reconnaissance Test
Anti-Surface Warfare
• Air-to-Surface Missile Test; Gunnery Test • Rocket Test • Laser Targeting
Electronic Warfare
• Electronic Systems Evaluation

Table 3.0-74: Testing Activities That Include Rotary-Wing Aircraft (continued)

Testing
Anti-Submarine Warfare
• Anti-Submarine Warfare Torpedo Test • Kilo Dip • Sonobuoy Lot Acceptance Test • Anti-Submarine Tracking Test – Helicopter
Mine Warfare
• Airborne Mine Neutralization Systems Test – ASQ-235 • Airborne Projectile-Based Mine Clearance System • Airborne Towed Minesweeping Test • Airborne Towed Minehunting Sonar Test • Airborne Laser-Based Mine Detection System Test • Mine Detection and Classification • Mine Countermeasure/Neutralization Testing
Other Testing – Naval Sea Systems Command
• Shipboard Electronic Systems Evaluation
New Ship Construction
• Anti-Submarine Warfare Mission Package Testing • Surface Warfare Mission Package Testing • Mine Countermeasure Mission Package Testing
Life Cycle Activities
• Combat System Ship Qualification Trial – Undersea Warfare
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Torpedo (Non-Explosive) Testing • Torpedo (Explosive) Testing

Table 3.0-75: Training Activities That Include Unmanned Aerial Systems

Training
Anti-Air Warfare
• Air Defense Exercises • Missile Exercise (Air-to-Air) • Missile Exercise (Surface-to-Air) • Missile Exercise – Man-portable Air Defense System
Amphibious Warfare
• Naval Surface Fire Support Exercise – Land-Based Target • Amphibious Raid
Anti-Surface Warfare
• Maritime Security Operations • Missile Exercise (Air-to-Surface) – Rocket

Table 3.0-75: Training Activities That Include Unmanned Aerial Systems (continued)

Training
Anti-Submarine Warfare
• Anti-Submarine Warfare for Composite Training Unit Exercise • Anti-Submarine Warfare for Joint Task Force Exercise/Sustainment Exercise

Table 3.0-76: Testing Activities That Include Unmanned Aerial Systems

Testing
Anti-Air Warfare
• Air Platform/Vehicle Test • Air Platform Weapons Integration Test • Intelligence, Surveillance, and Reconnaissance Test
New Ship Construction
• Surface Combatant Sea Trials – Missile Testing
Life Cycle Activities
• Combat System Ship Qualification Trial – Air Defense
Mine Warfare Testing
• Mine Detection and Classification Testing
Unmanned Vehicle Testing
• Underwater Deployed Unmanned Aerial System Testing • Unmanned Vehicle Development and Payload Testing
Other
• Shipboard Electronic Systems Evaluation

The location and number of events including aircraft movement is summarized in Table 3.0-77.

Table 3.0-77: Annual Number and Location of Events Including Aircraft Movement

Activity Area	Training			Testing		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
HRC	1,982	2,842	2,842	4,655	4,730	5,208
SOCAL	8,105	8,895	8,895	5,517	6,271	6,914
SSTC	536	536	536	0	0	0
Transit Corridor	0	11	11	0	0	0
Total	**10,623**	**12,284**	**12,284**	**10,172**	**11,001**	**12,122**

Notes: HRC = Hawaii Range Complex, SOCAL = Southern California (Range Complex), SSTC = Silver Strand Training Complex

3.0.5.3.4 Entanglement Stressors

This section describes the entanglement stressors introduced into the water through naval training and testing and the relative magnitude and location of these activities to provide the basis for analysis of potential impacts to resources in the remainder of Chapter 3. To assess the entanglement risk of materials expended during training and testing, the Navy examined the characteristics of these items (such as size and rigidity) for their potential to entangle marine animals. For a constituent of military

expended materials to entangle a marine animal, it must be long enough to wrap around the appendages of marine animals. Another critical factor is rigidity; the item must be flexible enough to wrap around appendages or bodies. This analysis includes the potential impacts from two types of military expended materials including: (1) fiber optic cables and guidance wires, and (2) parachutes.

Unlike typical fishing nets and lines, the Navy's equipment is not designed for trapping or entanglement purposes. 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.

3.0.5.3.4.1 Fiber Optic Cables and Guidance Wires

Fiber Optic Cables

The only type of cable expended during Navy training and testing are fiber optic cables. Fiber optic cables are flexible, durable, and abrasion or chemical-resistant and the physical characteristics of the fiber optic material render the cable brittle and easily broken when kinked, twisted, or bent sharply (i.e., to a radius greater than 360 degrees). The cables are often designed with controlled buoyancy to minimize the cable's effect on vehicle movement. The fiber optic cable would be suspended within the water column during the activity, and then be expended to sink to the sea floor.

Table 3.0-78 and Table 3.0-79 list the training and testing activities that include the use of fiber optic cables.

Table 3.0-78: Training Activities That Expend Fiber Optic Cables

Training
Mine Warfare
• Mine Countermeasure – Mine Neutralization – Remotely Operated Vehicle

Table 3.0-79: Testing Activities That Expend Fiber Optic Cables

Testing
Mine Warfare
• Airborne Mine Neutralization Systems Test • Mine Countermeasure/Neutralization Testing

The estimated location and number of expended fiber optic cables are detailed below in Table 3.0-80.

Table 3.0-80: Annual Number and Location of Events that Expend Fiber Optic Cable

Activity Area	Training			Testing		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
SOCAL	36	40	40	15	16	17
SSTC	208	208	208	0	0	0
Total	**244**	**248**	**248**	**15**	**16**	**17**

Notes: SOCAL = Southern California (Range Complex), SSTC = Silver Strand Training Complex

Guidance Wires

The only types of wires expended during Navy training and testing activities are guidance wires from heavy-weight torpedoes and tube-launched, optically tracked, wire guided missiles. Guidance wires are used to help the firing platform control and steer the torpedo or missile. They trail behind the torpedo or missile as it moves through the water or air. Finally, the guidance wire is released from both the firing platform and the torpedo or tube-launched, optically tracked, wire guided missile 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 42 lb. (19 kg) and can be broken by hand (Environmental Sciences Group 2005), contrasting with the rope or lines associated with commercial fishing towed gear (trawls), stationary gear (traps), or entanglement gear (gillnets) that utilize lines with substantially higher (up to 500–2,000 lb. [227–907 kg]) breaking strength as their "weak links" to minimize entanglement of marine animals (National Marine Fisheries Service 2008). The physical characteristics of the wire prevent it from tangling, unlike the monofilament fishing lines and polypropylene ropes identified in the literature (U.S. Department of the Navy 1996). Torpedo guidance wire sinks at an estimated rate of 0.7 ft. (0.2 m) per second.

The tube-launched, optically tracked, wire guided missile system has two thin (5.75 mils or 0.146 mm diameter) wires. Two wire dispensers containing several thousand meters each of single-strand wire with a minimum tensile strength of 10 lbs. are mounted on the rear of the missile. The length of wire dispensed would generally be equal to the distance the missile travels to impact the target and any undispensed wire would be contained in the dispensers upon impact. While degradation rates for the wire may vary because of changing environmental conditions in seawater, assuming a sequential failure or degradation of the enamel coating (degradation time is about two months), the copper plating (degradation time is about 1.5–25 months), and the carbon-steel core (degradation time is about 8–18 months), degradation of the tube-launched, optically tracked, wire guided missile guide wire would take 12–45 months. Table 3.0-81 and Table 3.0-82 list the training and testing activities that include the use of guidance wires.

Table 3.0-81: Training Activities That Expend Guidance Wires

Training
Anti-Surface Warfare
• Missile Exercise (Air-to-Surface) • Sinking Exercise
Anti-Submarine Warfare
• Tracking Exercise/Torpedo Exercise – Submarine • Submarine Command Course Operations
Major Training Events
• Joint Task Force Exercise/Sustainment Exercise • Rim of the Pacific Exercise

Table 3.0-82: Testing Activities That Expend Guidance Wires

Testing
Anti-Submarine Warfare
• Anti-Submarine Warfare Torpedo Test
Anti-Surface Warfare/Anti-Submarine Warfare Testing
• Torpedo (Non-Explosive) Testing • Torpedo (Explosive) Testing

The overall number of events per year that expend guidance wire and locations where they occur are detailed below in Table 3.0-83.

Table 3.0-83: Annual Number and Location of Events that Expend Guidance Wire

Activity Area	Training			Testing		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
HRC	142	135	135	160	232	249
SOCAL	64	65	65	240	248	291
Total	**206**	**200**	**200**	**400**	**480**	**540**

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

3.0.5.3.4.2 Parachutes

Aircraft-launched sonobuoys, lightweight torpedoes (such as the MK 46 and MK 54), illumination flares, and targets use nylon parachutes ranging in size from 18 to 48 in. (46 to 122 cm) in diameter. The majority of expended parachutes are relatively small cruciform decelerators associated with sonobuoys (Figure 3.0-17). Parachutes are made of cloth and nylon, many with weights attached to their short attachment lines to speed their sinking. Parachutes are made of cloth and nylon, and many have weights attached to the lines for rapid sinking. At water impact, the parachute assembly is expended, and it sinks away from the unit. The parachute assembly may remain at the surface for 5 to 15 seconds before the parachute and its housing sink to the seafloor, where it becomes flattened (Environmental Sciences Group 2005). Some parachutes are weighted with metal clips that facilitate their descent to the seafloor. Once settled on the bottom the canopy may temporarily billow if bottom currents are present.

Figure 3.0-17: Sonobuoy Launch Depicting the Relative Size of a Decelerator/Parachute

Training and testing activities that expend parachutes are listed in Table 3.0-53 and Table 3.0-54.

The estimated number of parachutes and locations where they would be expended are detailed below in Table 3.0-84.

Table 3.0-84: Annual Number and Location of Expended Parachutes

Activity Area	Training			Testing		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
HRC	26,250	26,000	26,000	1,859	4,217	4,542
SOCAL	18,250	28,000	28,000	5,371	8,361	9,234
Transit Corridor	0	200	200	0	0	0
Total	**44,500**	**54,200**	**54,200**	**7,230**	**12,578**	**13,776**

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

3.0.5.3.5 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 to provide the basis for analysis of potential impacts to resources in the remainder of Chapter 3. 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 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.

Solid metal materials, such as small-caliber projectiles, or fragments from high-explosive munitions, sink rapidly to the seafloor. Lighter items may be caught in currents and gyres or entangled in floating *Sargassum* and could remain in the water column for hours to weeks or indefinitely before sinking (e.g., plastic end caps or pistons).

3.0.5.3.5.1 Non-Explosive Practice Munitions

Only small- or medium-caliber projectiles 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. (57 mm) in diameter. These solid metal materials would quickly move through the water column and settle to the sea floor.

The training and testing activities that involve the use of small- and medium-caliber non-explosive practice munitions are listed in Table 3.0-39 through Table 3.0-42.

The overall number of expended small- and medium-caliber non-explosive practice munitions and locations where they occur can be found above in Table 3.0-65.

3.0.5.3.5.2 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 demolition charges, grenades, 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 munition type; however, typical sizes of fragments are unknown. These solid metal materials would quickly sink through the water column and settle to the seafloor.

The training and testing activities that involve fragments from high-explosives are listed in Table 3.0-59 and Table 3.0-60. The overall number of high-explosive munitions that may result in fragments, and the locations where they occur were detailed above in Table 3.0-66.

3.0.5.3.5.3 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, most of which are designed to be recovered for reuse. However, if they are used during activities that utilize high-explosives then they may result in fragments. Expendable targets that may result in fragments would include air-launched decoys, surface targets (such as marine markers, paraflares, 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 (see Section 2.3.3 for additional information on targets). Only targets that may result in smaller fragments are included in the analyses of ingestion potential.

The training and testing activities that may expend targets are listed in Table 3.0-61 and Table 3.0-62. The number and location per year of targets used during training and testing activities with the potential to result in small fragments were detailed above in Table 3.0-67.

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. 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 (U.S. Air Force 1997; Arfsten 2002). Doppler radar has tracked chaff plumes containing approximately 900 g of chaff drifting 200 mi. (322 km) from the point of release, with the plume covering greater than 400 $mi.^3$ (1,667 km^3) (Arfsten 2002).

The chaff concentrations that marine animals could be exposed to following 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 (U.S. Air Force 1997; Hullar 1999; Arfsten 2002). 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. 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. 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), Hullar et al. (1999), and U.S. 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 are either swallowed or expelled.

In laboratory studies conducted by the University of Delaware (Hullar 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. 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).

The training and testing activities that involve chaff are listed in Table 3.0-55 and Table 3.0-56. The estimated number of events per year that would involve expending chaff and locations where they occur are detailed below in Table 3.0-85.

Table 3.0-85: Annual Number and Location of Events Involve the Use of Expended Chaff

Activity Area	Training			Testing		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
HRC	200	2,600	2,600	0	300	300
SOCAL	20,750	20,750	20,750	0	204	254
Total	**20,950**	**23,350**	**23,350**	**0**	**504**	**554**

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

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 and fired from ships. 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. Flares are designed to burn completely. The only material that would enter the water would be a small, round, plastic end cap (approximately 1.4 in. [3.6 cm] in diameter).

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. Air Force 1997).

The training and testing activities that involve the use of flares are listed in Table 3.0-57 and Table 3.0-58. The overall number of flares expended annually is detailed below in Table 3.0-86.

Table 3.0-86: Annual Number and Location of Expended Flares

Activity Area	Training			Testing		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
HRC	1,750	1,750	1,750	0	45	50
SOCAL	8,300	8,300	8,300	0	350	385
Total	**10,050**	**10,050**	**10,050**	**0**	**395**	**435**

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

3.0.5.4 Resource-Specific Impacts Analysis for Individual Stressors

The direct and indirect impacts of each stressor carried forward for further analysis were analyzed for each resource in their respective section. Quantitative and semi-quantitative methods were used to the extent possible, but inherent scientific limitations required the use of qualitative methods for most stressor/resource interactions. Resource-specific methods are described in sections of Chapter 3, 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., $ft.^2$, nm^2) 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, injury, or mortality.
- 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.

3.0.5.5 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). In some ways, this analysis is similar to the cumulative impacts analysis described below, but it only considers the activities in the alternatives and not other past, present, and reasonably foreseeable future actions. This step helps focus the next steps of the approach (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 is such that mitigation would be necessary to offset adverse impacts.

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, 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.

3.0.5.6 Cumulative Impacts

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 nonfederal) or person undertakes the actions. Cumulative impacts result when individual actions combine with similar actions taking place over a period of time to produce conditions that frequently alter the historical baseline (40 C.F.R. § 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.

3.0.5.7 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

differential potential of biological resources to overlap with stressors was considered at the level of specific geographic areas (large marine ecosystems, open ocean areas, range complexes, operating areas, and other training and testing areas). Additionally, the differential impacts of training versus testing activities that introduce stressors to the resource were considered.

3.0.5.7.1 Conceptual Framework for Assessing Effects from Sound-Producing Activities

This conceptual framework describes the different types of effects that are possible and the potential relationships between sound stimuli and long-term consequences for the individual and population. The conceptual framework is central to the assessment of acoustic-related effects and is consulted multiple times throughout the process. It describes potential effects and the pathways by which an acoustic stimulus or sound-producing activity can potentially affect animals. The conceptual framework qualitatively describes costs to the animal (e.g., expended energy or missed feeding opportunity) that may be associated with specific reactions. Finally, the conceptual framework outlines the conditions that may lead to long-term consequences for the individual and population if the animal cannot fully recover from the short-term effects. Within each biological resource section (e.g., marine mammals, birds, and fish,) 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 sound-producing activities. The severity of these effects can vary greatly between minor effects that have no real cost to the animal, to more severe effects that may have lasting consequences. Whether a marine animal is significantly affected must be determined from the best available scientific data regarding the potential physiological and behavioral responses to sound-producing activities and the possible costs and long-term consequences of those responses.

The major categories of potential effects are:

- Direct trauma
- Auditory fatigue
- Auditory masking
- Behavioral reactions
- Physiological stress

Direct trauma refers to injury to organs or tissues of an animal as a direct result of an intense sound wave or shock wave impinging upon or passing through its body. Potential impacts on an animal’s internal tissues and organs are assessed by considering the characteristics of the exposure and the response characteristics of the tissues. Trauma can be mild and fully recoverable, with no long-term repercussions to the individual or population, or more severe, with the potential for lasting effects or, in some cases, mortality.

Auditory fatigue may result from over-stimulation of the delicate hair cells and tissues within the auditory system. The most familiar effect of auditory fatigue is hearing loss, also called a noise-induced threshold shift, meaning an increase in the hearing threshold.

Audible natural and artificial sounds can potentially result in auditory masking, a condition that occurs when noise interferes with an animal’s ability to hear other sounds and may affect the animal’s ability to communicate, such as requiring the animal to adjust the frequency or loudness of its call. Masking

occurs when the perception of a sound is interfered with by a second sound, and the probability of masking increases as the two sounds increase in similarity and the masking sound increases in level. It is important to distinguish auditory fatigue, which persists after the sound exposure, from masking, which occurs only during the sound exposure.

Marine animals naturally experience physiological stress as part of their normal life histories. Changing weather and ocean conditions, exposure to diseases and naturally occurring toxins, lack of prey availability, social interactions with conspecifics (members of the same species), and interactions with predators all contribute to the stress a marine animal naturally experiences. 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. However, too much of a stress response can be harmful to an animal, resulting in physiological dysfunction. In some cases, naturally occurring stressors can have profound impacts on animals. Sound-producing activities have the potential to provide additional stress, which must be considered, not only for its direct impact on an animal's behavior but also for contributing to an animal's chronic stress level.

A sound-producing activity can cause a variety of behavioral reactions in animals ranging from very minor and brief, to more severe reactions such as aggression or prolonged flight. The acoustic stimuli can cause a stress reaction (i.e., startle or annoyance); they may act as a cue to an animal that has experienced a stress reaction in the past to similar sounds or activities, or that acquired a learned behavioral response to the sounds from conspecifics. An animal may choose to deal with these stimuli or ignore them based on the severity of the stress response, the animal's past experience with the sound, as well as other stimuli present in the environment. If an animal chooses to react to the acoustic stimuli, then the behavioral responses fall into two categories: alteration of an ongoing behavior pattern or avoidance. The specific type and severity of these reactions helps determine the costs and ultimate consequences to the individual and population.

3.0.5.7.1.1 Flowchart

Figure 3.0-18 is a flowchart that diagrams the process used to evaluate the potential effects on marine animals from 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 acoustic waves but also shock waves generated from explosive sources. The supporting text clarifies those instances where it is necessary to distinguish between the two phenomena.

Box A1, the *Sound-Producing Activity*, is the source of the sound stimuli and therefore the starting point in the analysis. Each of the five major categories of potential effects (i.e., direct trauma, auditory fatigue, masking, behavioral response, and stress) are presented as pathways that flow from left to right across the diagram. Pathways are not exclusive, and each must be followed until it can be concluded that an animal is not at risk for that specific effect. The vertical columns show the steps in the analysis used to examine each of the effects pathways. These steps proceed from the *Stimuli,* to the *Physiological Responses*, to any potential *Behavioral Responses*, to the *Costs to the Animal*, to the *Recovery* of the animal, and finally to the *Long-Term Consequences* for the *Individual* and *Population*.

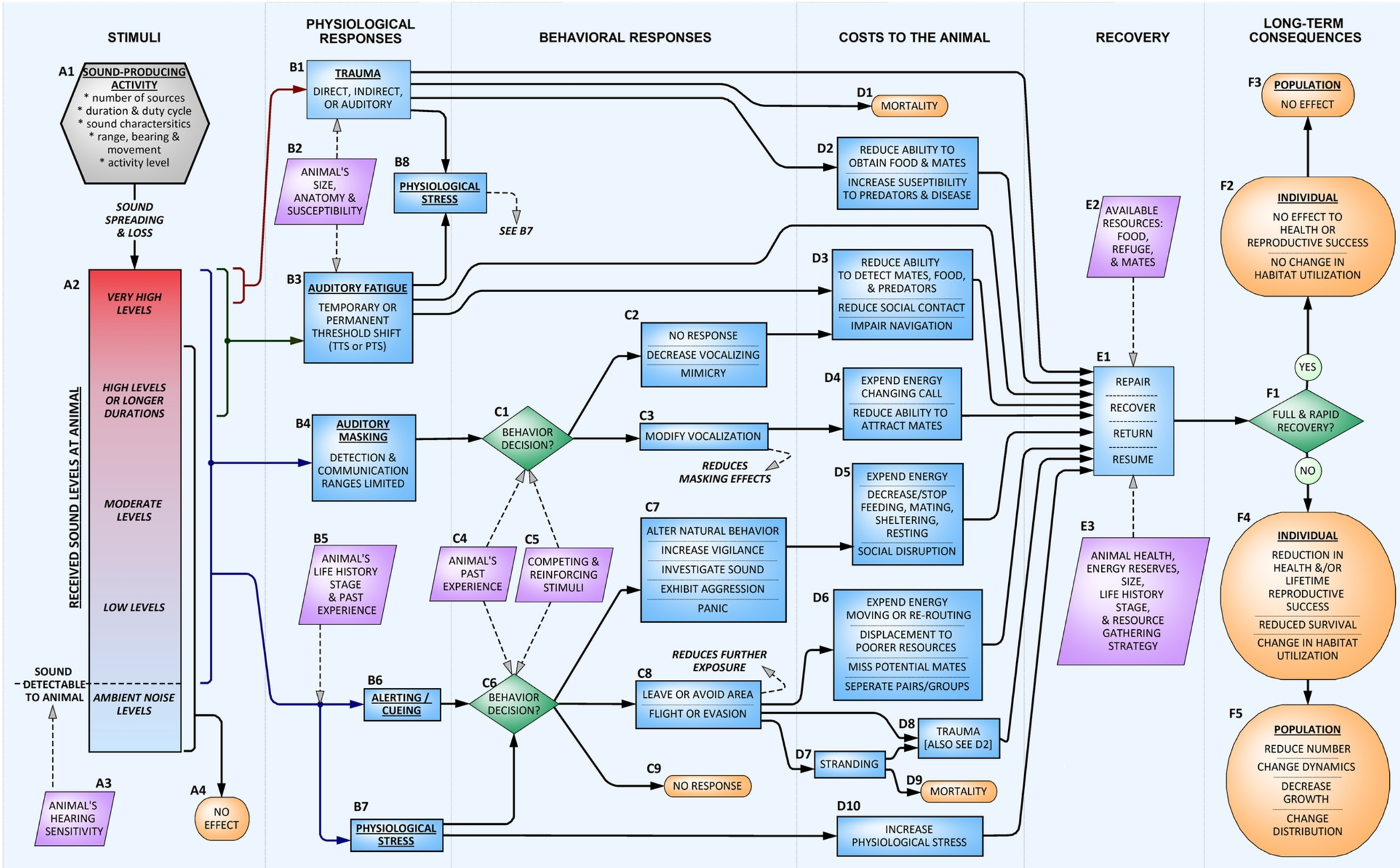


Figure 3.0-18: Flow Chart of the Evaluation Process of Sound-Producing Activities

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3.0.5.7.1.2 Stimuli

The first step in predicting whether a sound-producing activity is capable of causing an effect on a marine animal is to define the *Stimuli* experienced by the animal. The *Stimuli* include the *sound-producing activity*, the surrounding acoustical environment, and the characteristics of the sound when it reaches the animal, and whether the animal can detect the sound.

Sounds emitted from a *sound-producing activity* (Box A1) travel through the environment to create a spatially variable sound field. 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, several types of sonar, and several types of ordnance. Each of the individual sound sources has unique characteristics: source level, frequency, duty cycle, duration, and rise-time (i.e., impulsive vs. non-impulsive). Each source also has a range, depth/altitude, bearing and directionality, and movement relative to the animal.

Environmental factors such as temperature, salinity, bathymetry, bottom type, and sea state all impact how sound spreads through the environment and how sound decreases in amplitude between the source and the receiver (individual animal). Mathematical calculations and computer models are used to predict how the characteristics of the sound will change between the source and the animal under a range of realistic environmental conditions for the locations where sound-producing activities occur.

The details of the overall activity may also be important to place the potential effects into context and help predict the range of severity of the probable reactions. The overall activity level (e.g., number of ships and aircraft involved in exercise); the number of sound sources within the activity; the activity duration; and the range, bearing, and movement of the activity relative to the animal are all considered.

The *received sound at the animal* and the number of times the sound is experienced (i.e., repetitive exposures) (Box A2) determines the range of possible effects. 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. Very high exposure levels may have the potential to cause trauma; high-level exposures, long-duration exposures, or repetitive exposures may potentially cause auditory fatigue; lower-level exposures may potentially lead to masking; all perceived levels may lead to stress; and many sounds, including sounds that are not detectable by the animal, would have *no effect* (Box A4).

3.0.5.7.1.3 Physiological Responses

Physiological Responses include direct trauma, hearing loss, auditory masking, and stress. The magnitude of the involuntary response is predicted based on the characteristics of the acoustic stimuli and the characteristics of the animal (species, susceptibility, life history stage, size, and past experiences).

Trauma

Physiological responses to sound stimulation may range from mechanical vibration (with no resulting adverse effects) to tissue trauma (injury). Direct *trauma* (Box B1) refers to the direct injury of tissues and organs by sound waves impinging upon or traveling through an animal's body. Marine animals' bodies, especially their auditory systems, are well adapted to large hydrostatic pressures and large, but relatively slow, pressure changes that occur with changing depth. However, mechanical trauma may result from exposure to very-high-amplitude sounds when the elastic limits of the auditory system are exceeded or when animals are exposed to intense sounds with very rapid rise times, such that the tissues cannot respond adequately to the rapid pressure changes. Trauma to marine animals from sound

exposure requires high received levels. Trauma effects therefore normally only occur with very-high-amplitude, often impulsive, sources, and at relatively close range, which limits the number of animals likely exposed to trauma-inducing sound levels.

Direct trauma includes both auditory and non-auditory trauma. Auditory trauma is the direct mechanical injury to hearing-related structures, including tympanic membrane rupture, disarticulation of the middle ear ossicles, and trauma to the inner ear structures such as the organ of Corti and the associated hair cells. Auditory trauma 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 trauma is always injurious but can be temporary. One of the most common consequences of auditory trauma is hearing loss (see Auditory Fatigue below).

Non-auditory trauma 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 most sensitive organs and tissues to acoustic trauma. An *animal's size and anatomy* are important in determining its *susceptibility to trauma* (Box B2), especially non-auditory trauma. Larger size indicates more tissue to protect vital organs that might be otherwise susceptible (i.e., there is more attenuation of the received sound before it impacts non-auditory structures). Therefore, larger animals should be less susceptible to trauma 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 trauma. Resonance is a phenomenon that exists when an object is vibrated at a frequency near its natural frequency of vibration, or the particular frequency at which the object vibrates most readily. The size, geometry, and material composition of a structure determine the frequency at which the object will resonate. The potential for resonance is determined by comparing the sound frequencies with the resonant frequency and damping of the tissues. Because most biological tissues are heavily damped, the increase in susceptibility from resonance is limited.

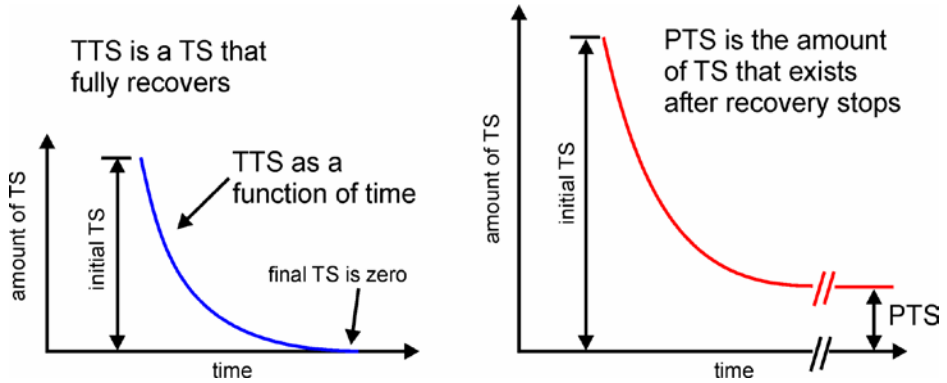
Vascular and tissue bubble formation resulting from sound exposure is a hypothesized mechanism of indirect trauma to marine animals. The risk of bubble formation from one of these processes, called rectified diffusion, is based on the amplitude, frequency, and duration of the sound (Crum and Mao 1996) and an animal's tissue nitrogen gas saturation at the time of the exposure. Rectified diffusion is the growth of a bubble that fluctuates in size because of the changing pressure field caused by the sound wave. An alternative, but related hypothesis, has also been suggested: stable microbubbles could be destabilized by high-level sound exposures such that bubble growth then occurs through static diffusion of gas out of gas-supersaturated tissues. Bubbles have also been hypothesized to result from changes in the dive behavior of marine mammals as a result of sound exposure (Jepson et al. 2003). Vascular bubbles produced by this mechanism would not be a physiological response to the sound exposure, but a cost to the animal because of the change in behavior (Section 3.0.5.7.1.5, Costs to the Animal). Under either of these hypotheses, several things could happen: (1) bubbles could grow to the extent that vascular blockage (emboli) and tissue hemorrhage occur, (2) bubbles could develop to the extent that a complement immune response is triggered or the nervous tissue is subjected to enough localized pressure that pain or dysfunction occurs, or (3) the bubbles could be cleared by the lung without negative consequence to the animal. Although rectified diffusion is a known phenomenon, its applicability to diving marine animals exposed to sound is questionable; animals would need to be highly supersaturated with gas and very close to a high-level sound source (Crum et al. 2005). The other two hypothesized phenomena are largely theoretical and have not been demonstrated under realistic exposure conditions.

Auditory Fatigue

Auditory fatigue is a reduction in hearing ability resulting from overstimulation to sounds. The mechanisms responsible for auditory fatigue differ from auditory trauma and may consist of a variety of mechanical and biochemical processes, including physical damage (not including tympanic membrane rupture) or distortion of the tympanic membrane and cochlear hair cell stereocilia, oxidative stress-related hair cell death, changes in cochlear blood flow, and swelling of cochlear nerve terminals resulting from glutamate excitotoxicity (Henderson et al. 2006; Kujawa and 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). Auditory fatigue is possibly the best studied type of effect from sound exposures in marine and terrestrial animals, including humans. 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 auditory fatigue.

Auditory fatigue manifests itself as hearing loss, called a noise-induced threshold shift. A threshold shift may be either permanent threshold shift (PTS), or temporary threshold shift (TTS). Note that the term "auditory fatigue" is often used to mean a TTS; however, in this analysis, a more general meaning to differentiate fatigue mechanisms (e.g., metabolic exhaustion and distortion of tissues) from auditory trauma mechanisms (e.g., physical destruction of cochlear tissues occurring at the time of exposure) is used.

The distinction between PTS and TTS is based on whether there is a complete recovery of hearing sensitivity following a sound exposure. 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.



TTS – temporary threshold shift
TS – threshold shift
PTS – permanent threshold shift

Figure 3.0-19: Two Hypothetical Threshold Shifts

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 2 minutes after exposure) will recover with no apparent long-term effects; however, terrestrial mammal studies revealed that large

amounts of TTS (e.g., approximately 40 dB measured 24 hours after exposure) can result in permanent neural degeneration, despite the hearing thresholds returning to normal (Kujawa and Liberman 2009). The amounts of TTS induced by Kujawa and Liberman were described as being "at the limits of reversibility." It is unknown whether smaller amounts of TTS can result in similar neural degeneration, or if effects would translate to other species such as marine animals.

The amplitude, frequency, duration, and temporal pattern of the sound exposure are important parameters for predicting the potential for auditory fatigue. Duration is particularly important because auditory fatigue is exacerbated with prolonged exposure time. The frequency of the sound also plays an important role in susceptibility to hearing loss. Experiments show that animals are most susceptible to *fatigue* (Box B3) within their most sensitive hearing range. Sounds outside of an animal's audible frequency range do not cause fatigue.

The greater the degree of threshold shift, the smaller the ocean space within which an animal can detect biologically relevant sounds and communicate. This is referred to as reducing an animal's "acoustic space." This reduction can be estimated given the amount of threshold shift incurred by an animal.

Auditory and Communication Masking

Auditory masking occurs if the noise from an activity interferes with an animal's ability to detect, understand, elicit, or recognize biologically relevant sounds of interest (Box B4). "Noise" refers to unwanted or unimportant sounds that mask an animal's ability to hear "sounds of interest" and affect an animal's ability to generate sounds (or call). A sound of interest refers to a sound that is potentially being detected. Sounds of interest include 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. Sounds of interest are frequently generated by conspecifics such as offspring, mates, and competitors.

The frequency, received level, and duty cycle of the noise determine the potential degree of auditory masking. Similar to hearing loss, the greater the degree of masking, the smaller the ocean space within which an animal can detect biologically relevant sounds.

Physiological Stress

If a sound is detected (i.e., heard or sensed) by an animal, a *stress* response can occur (Box B7); or the sound can *cue or alert* the animal (Box B6) without a direct, measurable stress response. If an animal suffers trauma or auditory fatigue, a *physiological stress* response will occur (Box B8). A stress response is a physiological change resulting from a stressor that is meant to help the animal deal with the stressor. The generalized stress response is characterized by a release of hormones (Reeder and Kramer 2005); however, it is now acknowledged that other chemicals produced in a stress response (e.g., stress markers) exist. For example, a release of reactive oxidative compounds, as occurs in noise-induced hearing loss (Henderson et al. 2006), occurs in response to some acoustic stressors. Stress hormones include those produced by the sympathetic nervous system, 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 produced by the adrenal gland. These hormones are classically used as an indicator of a stress response and to characterize the magnitude of the stress response (Hennessy et al. 1979). Oxidative stress occurs when reactive molecules, called reactive oxygen species, are produced in excess of molecules that counteract their activity (i.e., antioxidants).

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. Alternatively, a stimulus may not cause a measurable stress response but may act as an alert or cue to an animal to change its behavior. This response may occur because of learned associations; the animal may have experienced a stress reaction in the past to similar sounds or activities (Box C4), or it may have learned the response from conspecifics. The severity of the stress response depends on the *received sound level* at the animal (Box A2); the details of the *sound-producing activity* (Box A1); the *animal's life history stage* (e.g., juvenile or adult; breeding or feeding season) (Box B5); and the *animal's past experience* with the stimuli (Box B5). These factors would be subject to individual variation, as well as variation within an individual over time.

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. Animals engaged in a critical life activity such as mating or feeding may have a lesser stress response than an animal engaged in a more flexible activity such as resting or migrating (i.e., an activity that does not necessarily depend on the availability of resources). The animal's past experiences with the stimuli or similar stimuli are another important consideration. 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 and Dierauf 2001) or increase the response via sensitization.

3.0.5.7.1.4 Behavioral Responses

Any number of *Behavioral Responses* can result from a physiological response. An animal responds to the stimulus based on a number of factors in addition to the severity of the physiological response. An animal's experience with the sound (or similar sounds), the context of the acoustic exposure, and the presence of other stimuli contribute to determining its reaction from a suite of possible behaviors.

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.

Trauma and Auditory Fatigue

Direct trauma and auditory fatigue increases the animal's *physiological stress* (Box B8), which feeds into the *stress* response (Box B7). Direct trauma and auditory fatigue increase the likelihood or severity of a behavioral response and *increase* an animal's overall physiological stress level (Box D10).

Auditory Masking

A behavior decision 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 experience* with the sound -producing activity or similar acoustic stimuli can affect its choice of behavior during auditory masking (Box C4). *Competing and reinforcing stimuli* may also affect its decision (Box C5).

An animal may exhibit a passive behavioral response when coping with auditory 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, auditory masking will continue, depending on the acoustic stimuli.

An animal may actively compensate for auditory 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. For example, in marine mammals, vocalization changes have been reported from exposure to anthropogenic noise sources such as sonar, vessel noise, and seismic surveying. Changes included mimicry of the sound, cessation of vocalization, increases and decreases in vocalization length, increases and decreases in vocalization rate, and increases in vocalization frequency and level, while other animals showed no significant changes in the presence of anthropogenic sound.

An *animal's past experiences* can be important in determining what behavior decision it may make when dealing with auditory masking (Box C4). Past experience can be with the sound-producing activity itself or with similar acoustic stimuli. 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). These stimuli can be other acoustic stimuli not directly related to the sound-producing activity; they can be visual, olfactory, or tactile stimuli; the stimuli can be conspecifics or predators in the area; or the stimuli can be the strong drive to engage in a natural behavior. In some cases, natural motivations may suppress any behavioral reactions elicited by the acoustic stimulus. For example, an animal involved in mating or foraging may not react with the same degree of severity as it may have otherwise. Reinforcing stimuli reinforce the behavioral reaction caused by acoustic stimuli. For example, awareness of a predator in the area coupled with the acoustic stimuli may elicit a stronger reaction than the acoustic stimuli itself otherwise would have. The visual stimulus of seeing ships and aircraft, coupled with the acoustic stimuli, may also increase the likelihood or severity of a behavioral response.

Behavioral Reactions and Physiological Stress

A *physiological stress* response (Box B7) such as an annoyance or startle reaction, or a *cueing or alerting* reaction (Box B6) may cause an animal to make a *behavior decision* (Box C6). Any exposure that produces an injury or auditory fatigue is also assumed to produce a *stress* response (Box B7) and increase the severity or likelihood of a behavioral reaction. Both an animal's past 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).

Little data exist that correlate specific behavioral reactions with specific stress responses. Therefore, in practice the likely range of behavioral reactions is estimated from the acoustic stimuli instead of the magnitude of the stress response. It is assumed that a stress response must exist to alter a natural behavior or cause an avoidance reaction. Estimates of the types of behavioral responses that could occur for a given sound exposure have been determined from the literature.

An *animal's past experiences* can be important in determining what behavior decision it may make when dealing with a stress response (Box C4). Past experience can be with the sound-producing activity itself

or with similar sound stimuli. Bejder et. al (2009) define habituation as, "a process involving a reduction in response over time as individuals learn that there are neither adverse nor beneficial consequences of the occurrence of the stimulus." An animal habituated to a particular stimulus may have a lesser (or no) behavioral response to the stimulus compared to the first time the animal encountered the stimulus. Sensitization is the opposite of habituation, and refers to an increase over time in an animal's behavioral response to a repeated or continuous stimulus (Bejder et. al 2009). An animal sensitized to a particular stimulus exhibits an increasingly intense response to the stimulus (e.g., fleeing faster or farther), because there are significant consequences for the animal. A related behavioral response, tolerance, refers to an animal's ability to endure, or tolerate, a disturbance without a defined response. Habituation and sensitization are measured by the tolerance levels exhibited by animals; habituated animals show a progressively increasing tolerance to stimuli whereas sensitized animals show a progressively decreasing tolerance to stimuli (Bejder et. al 2009).

Other *stimuli* (Box C5) present in the environment can influence an animal's *behavior decision* (Box C6). These stimuli may not be directly related to the sound-producing activity, such as visual stimuli; the stimuli can be conspecifics or predators in the area, or the stimuli can be the strong drive to engage or continue in a natural behavior. In some cases, natural motivations (e.g., competing stimuli) may suppress any behavioral reactions elicited by the acoustic stimulus. For example, an animal involved in mating or foraging may not react with the same degree of severity as an animal involved in less-critical behavior. Reinforcing stimuli reinforce the behavioral reaction caused by acoustic stimuli. For example, the awareness of a predator in the area coupled with the acoustic stimuli may elicit a stronger reaction than the acoustic stimuli themselves otherwise would have.

The visual stimulus of seeing human activities such as ships and aircraft maneuvering, coupled with the acoustic stimuli, may also increase the likelihood or severity of a behavioral response. It is difficult to separate the stimulus of the sound from the visual stimulus of the ship or platform creating the sound. The sound may act as a cue, or as one stimulus of many that the animal is considering when deciding how to react. An activity with several platforms (e.g., ships and aircraft) may elicit a different reaction than an activity with a single platform, both with similar acoustic footprints. The total number of vehicles and platforms involved, the size of the activity area, and the distance between the animal and activity are important considerations when predicting behavioral responses.

An animal may reorient or become more *vigilant* if it detects a sound-producing activity (Box C7). Some animals may *investigate* the sound using other sensory systems (e.g., vision), and perhaps move closer to the sound source. *Reorientation, vigilance, and investigation* all require the animal to divert attention and resources and therefore slow or stop their presumably beneficial natural behavior. This can be a very brief diversion, after which the animal continues its natural behavior, or an animal may not resume its natural behaviors until after a longer period when the animal has habituated to or learned to tolerate the sound or the activity has concluded. An intentional change via an orienting response represents behaviors that would be considered mild disruption. More severe alterations of natural behavior would include *aggression or panic*.

An animal may choose to *leave or avoid an area* where a sound-producing activity is taking place (Box C8). Avoidance is the displacement of an individual from an area. A more severe form of this comes in the form of flight or evasion. A flight response is a dramatic change in normal movement to a directed and rapid movement away from the detected location of a sound source. Avoidance of an area can help the animal avoid further acoustic effects by avoiding or reducing further exposure.

An animal may choose *not to respond* to a sound-producing activity (Box C9). The physiological stress response may not rise to the level that would cause the animal to modify its behavior. The animal may have habituated to the sound or simply learned through past experience that the sound is not a threat. In this case a behavioral effect would not be predicted. An animal may choose not to respond to a sound-producing activity in spite of a physiological stress response. Some combination of competing stimuli may be present such as a robust food patch or a mating opportunity that overcomes the stress response and suppresses any potential behavioral responses. If the noise-producing activity persists over long periods or reoccurs frequently, the stress felt by animals could increase their chronic stress levels.

3.0.5.7.1.5 Costs to the Animal

The potential costs to a marine animal from an involuntary or behavioral response include no measurable cost, expended energy reserves, increased stress, reduced social contact, missed opportunities to secure resources or mates, displacement, and stranding or severe evasive behavior (which may potentially lead to secondary trauma or death). Animals suffer costs on a daily basis from a host of natural situations such as dealing with predator or competitor pressure. If the costs to the animal from an acoustic-related effect fall outside of its normal daily variations, then individuals must recover from significant costs to avoid long-term consequences.

Trauma

Trauma or injury to an animal may *reduce its ability to secure food* by *reducing its mobility* or the efficiency of its sensory systems, make the injured individual *less attractive to potential mates*, or increase *an individual's chances of contracting diseases or falling prey to a predator* (Box D2). A severe trauma can lead to the *death* of the individual (Box D1).

Auditory Fatigue and Auditory Masking

Auditory fatigue and masking can impair an animal's ability to hear biologically important sounds (Box D3), especially fainter and distant sounds. Sounds could belong to conspecifics such as other individuals in a social group (i.e., pod, school, etc.), potential mates, potential competitors, or parents/offspring. Biologically important sounds could also be an animal's own biosonar echoes used to detect prey, sounds from predators, and sounds from the physical environment. Therefore, auditory masking or a hearing loss could reduce an animal's ability to contact social groups, offspring, or parents; and reduce opportunities to detect or attract more distant mates. Animals may also use sounds to gain information about their physical environment by detecting the reverberation of sounds in the underwater space or sensing the sound of crashing waves on a nearby shoreline. These cues could be used by some animals to migrate long distances or navigate their immediate environment. Therefore, an animal's ability to navigate may be impaired if the animal uses acoustic cues from the physical environment to help identify its location. Auditory masking and fatigue both effectively reduce the animal's acoustic space and the ocean volume in which detection and communication are effective.

An animal that modifies its vocalization in response to auditory masking could incur a cost (Box D4). Modifying vocalizations may cost the animal energy from its finite energy budget, 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 and Ripmeester 2008). Increasing the frequency of these vocalizations could

reduce a signaler's attractiveness in the eyes of potential mates even as it improves the overall detectability of the call.

Auditory masking or auditory fatigue may also lead to no measurable costs for an animal. Masking could be of short duration or intermittent so that continuous or repeated biologically important sounds are received by the animal between masking noise. Auditory fatigue could also be inconsequential for an animal if the frequency range affected is not critical for that animal to hear within, or the auditory fatigue is of such short duration (a few minutes) that there are no costs to the individual.

Behavioral Reactions and Physiological Stress

An animal that alters its natural behavior in response to stress or an auditory cue may slow or cease its presumably beneficial natural behavior and instead *expend energy* reacting to the sound-producing activity (Box D5). Beneficial 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. Most behavior alterations also require the animal to expend energy for a nonbeneficial behavior. The amount of energy expended depends on the severity of the behavioral response.

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). Avoidance reactions can cause an animal to expend energy. The amount of energy expended depends on the severity of the behavioral response. Missing potential mates can result in delaying reproduction. Social groups or pairs of animals, such as mates or parent/offspring pairs, could be separated during a severe behavioral response such as flight. 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 *trauma* (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 *trauma* is likely to occur to an animal that strands (Box D8). Trauma 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 quickly will likely *die* (Box D9).

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 an animal's initial stress response during the behavior decision. Regardless of whether the animal displays a behavioral reaction, this tolerated stress could incur a cost to the animal. Reactive oxygen species produced during normal physiological processes are generally counterbalanced by enzymes and antioxidants; however, excess stress can result in an excess production of reactive oxygen species, leading to damage of lipids, proteins, and nucleic acids at the cellular level (Sies 1997; Touyz 2004).

3.0.5.7.1.6 Recovery

The predicted recovery of the animal (Box E1) is based on the cost of any masking or behavioral response and the severity of any involuntary physiological reactions (e.g., direct trauma, hearing loss, or increased chronic stress). Many effects are fully recoverable upon cessation of the sound-producing

activity, and the vast majority of effects are completely recoverable over time; whereas a few effects may not be fully recoverable. The availability of resources and the characteristics of the animal play a critical role in determining the speed and completeness of recovery.

Available resources fluctuate by season, location, and year and can play a major role in an animal's rate of recovery (Box E2). Plentiful *food* can aid in a quicker recovery, whereas recovery can take much longer if food resources are limited. If many potential *mates* are available, an animal may recover quickly from missing a single mating opportunity. *Refuge* or shelter is also an important resource that may give an animal an opportunity to recover or repair after an incurred cost or physiological response.

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 will likely recover more quickly. Adult animals with stored energy reserves (e.g., fat reserves) may have an easier time recovering than juveniles that expend their energy growing and developing and have less in reserve. Large individuals and large species may recover more quickly, also due to having more potential for energy reserves. Animals that gather and store resources, perhaps fasting for months during breeding or offspring rearing seasons, may have a more difficult time recovering from being temporarily displaced from a feeding area than an animal that feeds year round.

Damaged tissues from mild to moderate trauma may heal over time. The predicted recovery of direct trauma is based on the severity of the trauma, availability of resources, and characteristics of the animal. After a sustained injury an animal's body attempts to *repair* tissues. 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 (Box E1). Moderate to severe trauma that does not cause mortality may never fully heal.

Small to moderate amounts of hearing loss may recover over a period of minutes to days, depending on the nature of the exposure and the amount of initial threshold shift. Severe noise-induced hearing loss may not fully recover, resulting in some amount of permanent hearing loss.

Auditory masking only occurs when the sound source is operating; therefore, direct masking effects stop immediately upon cessation of the sound-producing activity (Box E1). Natural behaviors may *resume* shortly after or even during the acoustic stimulus after an initial assessment period by the animal. Any energetic expenditures and missed opportunities to find and secure resources incurred from masking or a behavior alteration may take some time to *recover*.

Animals displaced from their normal habitat due to an avoidance reaction may *return* over time and *resume* their natural behaviors, depending on 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 or learn to tolerate the new baseline or fluctuations in noise level. More sensitive species, or animals that may have been sensitized to the stimulus over time due to past negative experiences, may not return to an area. Other animals may return but not resume use of the habitat in the same manner as before the acoustic-related effect. For example, an animal may return to an area to feed or navigate through it to get to another area, but that animal may no longer seek that area as refuge or shelter.

Frequent milder physiological responses to an individual may accumulate over time if the time between sound-producing activities is not adequate to give the animal an opportunity to fully recover. An increase in an animal's chronic stress level is also possible if stress caused by a sound-producing activity

does not return to baseline between exposures. Each component of the stress response is variable in time, and stress hormones return to baseline levels at different rates. For example, adrenaline is released almost immediately and is used or cleared by the system quickly, whereas glucocorticoid and cortisol levels may take long periods (i.e. hours to days) to return to baseline.

3.0.5.7.1.7 Long-Term Consequences to the Individual and the Population

The magnitude and type of effect and the speed *and completeness of recovery* must be considered in predicting long-term consequences to the individual animal and its population (Box E). Animals that recover quickly and completely from explosive or acoustic-related effects will likely *not 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 utilize the environment*; or they could *die* (Box F1).

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.

An animal whose hearing does not recover quickly and fully could suffer a reduction in lifetime reproductive success, because it may no longer be able to detect the calls of a mate as well as it could prior to losing hearing sensitivity(Box F1). This example underscores the importance of the frequency of sound associated with the hearing loss and how the animal relies on those frequencies (e.g., for mating, navigating, detecting predators). An animal with decreased energy stores or a 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.

As mentioned above, the direct effects of masking ends when the acoustic stimuli conclude. The direct effects of auditory masking could have long-term consequences for individuals if the activity was continuous or occurred frequently enough; however, most of the proposed training and testing activities are normally spread over vast areas and occur infrequently in a specific area.

Missed mating opportunities can have a direct effect on reproductive success. Reducing an animal's energy reserves over longer periods can directly reduce its health and reproductive success. Some species may not enter a breeding cycle without adequate energy stores, and animals that do breed may have a decreased probability of offspring survival. Animals displaced from their preferred habitat, or those who utilize it differently, may no longer have access to the best resources. Some animals that leave or flee an area during a noise-producing activity, especially an activity that is persistent or frequent, may not return quickly or at all. This can further reduce an individual's health and lifetime reproductive success.

Frequent disruptions to natural behavior patterns may not allow an animal to fully recover between exposures, which increase the probability of causing long-term consequences to individuals. Elevated chronic stress levels are usually a result of a prolonged or repeated disturbance. Excess stress produces reactive molecules in an animal's body that can result in cellular damage (Sies 1997; Touyz 2004).

Chronic elevations in the stress levels (e.g., cortisol levels) may produce long-term health consequences that can reduce lifetime reproductive success.

These long-term consequences to the individual can lead to consequences for the *population* (Box G1). 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 (Box G1). Long-term abandonment or a change in the utilization of an area by enough individuals can *change the distribution* of the population. Death has an immediate effect in that no further contribution to the population is possible, which reduces the animal's lifetime reproductive success.

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, the lifetime reproductive success in individuals may decrease due to finite resources or predator-prey interactions. *Population 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 effects on a few individuals may not be affected overall.

Populations that exist well below their carrying capacity (e.g., threatened or endangered species populations) may suffer greater consequences from any lasting effects on 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. Changing the dynamics of a population (the proportion of the population within each age group) or their geographic distribution can also have secondary effects on population growth rates.

3.0.5.7.2 Conceptual Framework for Assessing Effects from Energy-Producing Activities

3.0.5.7.2.1 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 (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). The only types of lasers considered for analysis were low to moderate lasers (e.g., targeting systems, detection systems, laser light detection and ranging) that do not pose a risk to organisms (Swope 2010), and therefore; will not be discussed further.

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. The greatest potential electromagnetic energy exposure is at the source, where intensity is greatest. The greatest potential for high energy laser exposure is at the ocean’s surface, where high energy laser intensity is greatest. As the laser penetrates the water, 96 percent of the beam is absorbed, scattered, or otherwise lost (Zorn 2000; Ulrich 2004).

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 particularly considered those species known to inhabit the surface of the ocean.

3.0.5.7.2.2 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 (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. As with humans, the greatest laser-related concern for marine species is damage to an organism's ability to see. High energy lasers may also burn the skin, but the threshold energy level for eye damage is considerably lower, so the analysis considered that lower threshold. Recovery of the individual from eye damage or skin lesion caused by high energy lasers would be based on the severity of the injury and the incidence of secondary infection. Very few studies of this impact are available.

3.0.5.7.2.3 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. When stressors are chronic, an organism may experience reduced growth, health, or survival, which could have population-level impacts (Billard et al. 1981), especially in the case of endangered species.

3.0.5.7.3 Conceptual Framework for Assessing Effects from Physical Disturbance or Strike

3.0.5.7.3.1 Stimuli

Size and Weight of the Objects

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. 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 because they are planktonic (floating organisms) and move with the water; however, animals that occur at or near the surface could be struck. A larger nonplanktonic organism could potentially be struck by an object since it may not be displaced by the movement of the water. Sessile (nonmobile) organisms and habitats could be struck by the object, albeit with less force, on the seafloor. 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 parachute, flare end cap, or chaff canister).

Location and Speed of the Objects

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. Once landed on the water surface, buoyant objects have the potential to strike plants and organisms that occur on the sea surface (e.g., drifting into *Sargassum* mats), and negatively buoyant objects may strike plants and organisms 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.

3.0.5.7.3.2 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.

3.0.5.7.3.3 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. When stressors are chronic, an organism may experience reduced growth, health, or survival, which could have population-level impacts (Billard et al. 1981), especially in the case of endangered species.

3.0.5.7.4 Conceptual Framework for Assessing Effects from Entanglement

3.0.5.7.4.1 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.

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., 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.

3.0.5.7.4.2 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.

3.0.5.7.4.3 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.

3.0.5.7.5 Conceptual Framework for Assessing Effects from Ingestion

3.0.5.7.5.1 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 ordnance fragments), sink rapidly to the seafloor. More buoyant materials include less dense items (e.g., target fragments and parachutes) that may be caught in currents and gyres or entangled in floating *Sargassum*. These materials can remain in the water column for an indefinite period of time before sinking. However, 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).

3.0.5.7.5.2 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.

3.0.5.7.5.3 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.

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REFERENCES

Allen, M. J., Groce, A. K., Diener, D., Brown, J., Steinert, S. A., Deets, G., Mikel, T. (2002). *Southern California Bight 1998 Regional Monitoring Program: V. Demersal Fishes and Megabenthic Invertebrates*. (pp. 572). Westminster, CA: Southern California Coastal Water Research Project.

American National Standards Institute. (1994). ANSI S1.1-1994 (R 2004) American National Standard Acoustical Terminology (Vol. S1.1-1994 (R 2004)). New York, NY: Acoustical Society of America.

Andrew, R. K., Howe, B. M., Mercer, J. A., & Dzieciuch, M. A. (2002). Ocean ambient sound: comparing the 1960s with the 1990s for a receiver off the California coast. Acoustics Research Letters Online, 3, 65.

Arfsten, D., Wilson, C. & Spargo, B. (2002, July 25). Radio Frequency Chaff: The Effects of Its Use in Training on the Environment. *Ecotoxicology and Environmental Safety, 53*, 1-11. 10.1006

Aquarone, M. C. & Adams, S. (2009). XIX-63 Insular Pacific-Hawaiian: LME #10. In *The UNEP Large Marine Ecosystem Report: A Perspective on Changing Conditions in LMEs of the World's Regional Seas* United Nations Environmental Programme (UNEP Regional Seas Report and Studies pp. 829-838). Retrieved from http://www.lme.noaa.gov/index.php?option=com_content&view=article&id=56:lme10&catid=41:briefs&Itemid=72, 15 February 2012.

Au, W. W. L. (1993). The Sonar of Dolphins (pp. 227). New York: Springer-Verlag.

Au, W. W. L. & Banks, K. (1998). The acoustics of the snapping shrimp *Synalpheus parneomeris* in Kaneohe Bay. *Journal of the Acoustical Society of America, 103*(1), 41-47.

Baggeroer, A. & Munk, W. (1992). The Heard Island feasibility test. *Physics Today*, 22-30.

Barber, R. T. & Chavez, F. P. (1983). Biological consequences of El Niño. *Science, 222*(4629), 1203-1210.

Barber, R. T., Kogelschatz, J. E. & Chavez, F. P. (1985). Origin of productivity anomalies during the 1982-83 El Niño. *CalCOFI Reports, 26*, 65-71.

Batteen, M. L., Cipriano, N. J. & Monroe, J. T. (2003). A large-scale seasonal modeling study of the California Current System. *Journal of Oceanography, 59*(5), 545-562.

Bejder, L., Samuels, A., Whitehead, H., Finn, H. & Allen, S. (2009, December 03). Impact assessment research: use and misuse of habituation, sensitisation and tolerance in describing wildlife responses to anthropogenic stimuli. *Marine Ecology Progress Series, 395*, 177-185. 10.3354/meps07979 Retrieved from http://www.int-res.com/abstracts/meps/v395/p177-185/

Billard, R., Bry, C. & Gillet, C. (1981). Stress, environment and reproduction in teleost fish A. D. Pickering (Ed.), *Stress and Fish*. New York: Academic Press Inc.

Blanton, J. & Pattullo, J. G. (1970). The subsurface boundary between subarctic Pacific water and Pacific equatorial water in the trasition zone off Southern California. *Limnology and Oceanography, 15*, 606-614.

Bograd, S. J. (2004). California current. In *Marine Ecosystems of the North Pacific*. (PICES Special Publication 1, pp. 177-191) North Pacific Marine Science Organization. Available from http://www.pices.int/publications/special_publications/NPESR/2005/npesr_2005.aspx

Bograd, S. J., DiGiacomo, P. M., Durazo, R., Hayward, T. L., Hyrenbach, K. D., Lynn, R. J., Moore, C. S. (2000). The State of the California Current, 1999-2000: Forward to a new regime? *CalCOFI Report, 41*, 26-52.

Bousman, W. G. and R. M. Kufeld. (2005). UH-60A Airloads Catalog, NASA TM 2005212827. [August.]

California Department of Transportation (CALTRANS). (2009). Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish ICF Jones & Stokes and Illingworth and Rodkin, Inc. (Eds.). Sacramento, CA.

Campbell, R. R., Yurick, D. B. & Snow, N. B. (1988). Predation on narwhals, *Monodon monoceros*, by killer whales, *Orcinus orca*, in the Eastern Canadian Arctic. *Canadian Field-Naturalist, 102*(4), 689-696.

Castro, C. & Huber, M. E. (2007). Chemical and physical features of seawater and the world Ocean. In *Marine Biology* (6th ed., pp. 45-68). New York, NY: McGraw-Hill.

Chavanne, C., Flament, P., Lumpkin, R., Dousset, B. & Bentamy, A. (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. & Niiler, P. P. (1994). Circulation in the Ensenada Front - September 1988. *Deep-Sea Research I, 41*(8), 1251-1287. doi: 10.1016/0967-0637(94)90043-4

Coale, K. H., Johnson, K. S., Fitzwater, S. E., Blain, S. P. G., Stanton, T. P. & Coley, T. L. (1998). IronEx-I, an *in situ* iron-enrichment experiment: Experimental design, implementation and results. *Deep-Sea Research II, 45*, 919-945.

Coale, K. H., Johnson, K. S., Fitzwater, S. E., Gordon, R. M., Tanner, S., Chavez, F. P., Kudela, R. (1996). A massive phytoplankton bloom induced by an ecosystem-scale iron fertilization experiment in the Equatorial Pacific. *Nature 383*, 495-501.

Covault, J. A., Normark, W. R., Romans, B. W. & Graham, S. A. (2007). Highstand fans in the California borderland: The overlooked deep-water depositional system. *Geology, 35*(9), 783-786. doi: 10.1130/G23800A.1

Crum, L. & Mao, Y. (1996, May). Acoustically enhanced bubble growth at low frequencies and its implications for human diver and marine mammal safety. *Acoustical Society of America, 99*(5), 2898-2907.

Crum, L., Bailey, M., Guan, J., Hilmo, P., Kargl, S. & Matula, T. (2005, July). 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. 10.1121/1.1930987

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. doi: 10.1016/s0967-0645(03)00125-5

Dickson, R. R. & Brown, J. (1994). The production of North Atlantic Deep Water: Sources, rates, and pathways. *Journal of Geophysical Research, 99*(C6), 12319-12341. 10.1029/94jc00530

Dorman, C. E. (1982). Winds between San Diego and San Clemente Island. *Journal of Geophysical Research, 87*(C12), 9636-9646.

Duda, A. M. & Sherman, K. (2002). A new imperative for improving management of large marine ecosystems. *Ocean & Coastal Management, 45*(11-12), 797-833. doi:10.1016/S0964-5691(02)00107-2

Eller, A. I. & Cavanagh, R. C. (15118). (2000). Subsonic aircraft noise at and beneath the ocean surface: estimation of risk for effects on marine mammals. (Vol. AFRL-HE-WP-TR-2000-0156).

Environmental Sciences Group. (2005). *CFMETR Environmental Assessment Update 2005*. (RMC-CCE-ES-05-21, pp. 652). Kingston, Ontario: Environmental Sciences Group, Royal Military College.

Flament, P., Kennan, S., Lumpkin, R., Sawyer, M. & Stroup, E. D. (2009, Last updated 11 August 2009). *Ocean Atlas of Hawaii.* School of Ocean and Earth Science and Technology, University of Hawai'i. Retrieved from http://www.soest.hawaii.edu/hioos/oceanatlas/marclimat.htm, 02 June 2010.

Fletcher, C. H., III, Grossman, E. E., Richmond, B. M. & Gibbs, A. E. (2002). *Atlas of Natural Hazards in the Hawaiian Coastal Zone*. (Geologic Investigations Series I-2761, pp. 182). Denver, CO: U.S. Department of the Interior and U.S. Geological Survey.

Garrison, T. (1998). Seawater chemistry. In *Oceanography: An Invitation to Marine Science* (3rd ed., pp. 138-153). Belmont, CA: Wadsworth Publishing Company.

Gay, P. S. & Chereskin, T. K. (2009). Mean structure and seasonal variability of the poleward undercurrent off Southern California. *Journal of Geophysical Research, 114*, C02007. doi: 10.1029/2008JC004886

Gelpi, C. G. & Norris, K. E. (2008). Seasonal temperature dynamics of the upper ocean in the Southern California Bight. *Journal of Geophysical Research, 113*, C04034. doi: 10.1029/2006JC003820

General Bathymetric Chart of the Oceans. (2010). General Bathymetric Chart of the Oceans (GEBCO) Digital Atlas Undersea Features - Lines [GIS data]. *GEBCO Digital Atlas*. (Centenary ed.). Norfolk, VA: U. S. Department of the Navy, Naval Facilities Engineering Command, Atlantic.

Gergis, J. L. & Fowler, A. M. (2009). A history of ENSO events since A.D.1525: implications for future climate change. *Climatic Change, 92*(3), 343-387. doi: 10.1007/s10584-008-9476-z

Goreau, T. J. & Hayes, R. L. (1994). Coral bleaching and ocean "hot spots". *Ambio, 23*, 176-180.

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. doi: 10.1016/0079-6611(92)90008-n

Hamernik, R. P. & Hsueh, K. D. (1991, July). Impulse noise: some definitions, physical acoustics and other considerations. [special]. *Journal of the Acoustical Society of America, 90*(1), 189-196.

Hatch, L., Clark, C., Merrick, R., Van Parijs, S., Ponirakis, D., Schwehr, K., Wiley, D. (2008). Characterizing the relative contributions of large vessels to total ocean noise fields: A case study using the Gerry E. Studds Stellwagen Bank National Marine Sanctuary. *Environmental Management, 42*, 735-752. doi:10.1007/s00267-008-9169-4

Hayward, T. L. (2000). El Niño 1997-98 in the coastal waters of Southern California: A timeline of events. *CalCOFl Reports, 41*, 98-116.

Heileman, S. & Mahon, R. (2009). XV-49 Caribbean Sea: TAG: LME #12. In K. Sherman and G. Hempel (Eds.), *The UNEP Large Marine Ecosystem Report: A Perspective on Changing Conditions in LMEs of the World's Regional Seas*. (UNEP Regional Seas Report and Studies No. 182, pp. 657-671). Nairobi, Kenya: United Nations Environmental Programme. Available from http://www.lme.noaa.gov/index.php?option=com_content&view=article&id=58:lme12&catid=41:briefs&Itemid=72

Henderson, D., Bielefeld, E. C., Harris, K. C. & Hu, B. H. (2006). The role of oxidative stress in noise-induced hearing loss. *Ear and Hearing, 27*(1), 1-19.

Hennessy, M.B., Heybach, J.P., Vernikos, J., & Levine, S. (1979). Plasma corticosterone concentrations sensitively reflect levels of stimulus inensity 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. doi: 10.1016/0079-6611(92)90009-o

Hill, R.D. (1985). Investigation of lightning strikes to water surfaces. *Journal of the Acoustical Society of America*, 78(6), 2096-2099.

Howell, E. A., Dutton, P. H., Polovina, J. J., Bailey, H., Parker, D. M. & Balazs, G. H. (2010). Oceanographic influences on the dive behavior of juvenile loggerhead turtles (*Caretta caretta*) in the North Pacific Ocean. *Marine Biology, 157*(5), 1011-1026. doi: 10.1007/s00227-009-1381-0

Hullar, T., Fales, S., Hemond, H., Koutrakis, P., Schlesinger, W., Sobonya, R., Watson, J. (1999). Environmental Effects of RF Chaff A Select Panel Report to the Undersecretary of Defense for Environmental Security U.S. Department of the Navy and N. R. Laboratory (Eds.), [Electronic Version]. (pp. 84).

Hunter, E., Chant, R., Bowers, L., Glenn, S. & Kohut, J. (2007). Spatial and temporal variability of diurnal wind forcing in the coastal ocean. *Geophysical Research Letters, 34*(3), L03607. doi:10.1029/2006gl028945

Intergovernmental Oceanographic Commission. (2009). 2nd Fleet 100m Bathymetric Contour Interval Between 100m and 5000m [CD-ROM]. *GEBCO Digital Atlas*. (Centenary ed.). Liverpool, U.K: International Hydrographic Organization, British Oceanographic Data Centre, and the U. S. Department of the Navy.

International Council for the Exploration of the Sea. (2005). *Answer to DG Environment Request on Scientific Information Concerning Impact of Sonar Activities on Cetacean Populations*. (pp. 6). Copenhagen, Denmark: International Council for the Exploration of the Sea. Available from European Commission website: http://ec.europa.eu/environment/nature/conservation/species/whales_dolphins/

Investigative Science and Engineering, Inc. (1997). Noise Measurements of Various Aircraft and Ordnance at San Clemente Island. 1997.

Itano, D. G. & Holland, K. N. (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*, 213-223.

Jepson, P., Arbelo, M., Beaville, R., Patterson, I., Castro, P., Baker, J., Fernandez, A. (2003, October). Gas-bubble lesions in stranded cetaceans Was sonar responsible for a spate of whale deaths after an Atlantic military exercise? *Nature, 425*.

Johnson, G. C. (2008). Quantifying Antarctic bottom water and North Atlantic deep water volumes. *Journal of Geophysical Research, 113*, C05027. doi: 10.1029/2007JC004477

Johnson, K. S., Riser, S. C. & Karl, D. M. (2010). Nitrate supply from deep to near-surface waters of the North Pacific subtropical gyre. *Nature, 465*(7301), 1062-1065. doi: 10.1038/nature09170

Kawabe, M. & Fujito, S. (2010). Pacific Ocean circulation based on observation. *Journal of Oceanography, 66*, 389-403.

Kinsler, L. E., Frey, A. R., Coppens, A. B. & Sanders, J. V. (1982). Fundamentals of Acoustics (3rd ed.). New York, NY: Wiley.

Krishnamurthy, A., Moore, J. K., Mahowald, N., Luo, C., Doney, S. C., Lindsay, K. & Zender, C. S. (2009). Impacts of increasing anthropogenic soluble iron and nitrogen deposition on ocean biogeochemistry. *Global Biogeochemical Cycles, 23*, 15. doi: 10.1029/2008GB003440

Kujawa, S. G. & Liberman, M. C. (2009, November 11). Adding insult to injury: cochlear nerve degeneration after "temporary" noise-induced hearing loss. *J Neurosci, 29*(45), 14077-14085. 29/45/14077 [pii] 10.1523/JNEUROSCI.2845-09.2009 Retrieved from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=19906956

Laney, H. & Cavanagh, R. C. (15117). (2000). Supersonic aircraft noise at and beneath the ocean surface: estimation of risk for effects on marine mammals. (Vol. AFRL-HE-WP-TR-2000-0167, pp. 1-38).

Langmann, B., Zaksek, K., Hort, M. & Duggen, S. (2010). Volcanic ash as fertiliser for the surface ocean. *Atmospheric Chemistry and Physics, 10*, 3891-3899. doi:10.5194/acp-10-3891-2010

Laughlin, J. (2005). Underwater Sound Levels Associated with Pile Driving at the Bainbridge Island Ferry Terminal Preservation Project *WSF Bainbridge Island Ferry Terminal Preservation Project*. Washington State Department of Transportation.

Laughlin, J. (2010, 4 May). Keystone Ferry Terminal - Vibratory Pile Monitoring Technical Memorandum. J. Callahan and R. Huey, Washington State Department of Transportation (WSDOT).

Leet, W. S., Dewees, C. M., Klingbeil, R. & Larson, E. J. (2001). *California's Living Marine Resources: A Status Report*. (SG 01-11, pp. 593) California Department of Fish and Game. Available from www.dfg.ca.gov/mrd

Levenson, C. (1974). Source level and bistatic target strength of the sperm whale (*Physeter catodon*) measured from an oceanographic aircraft. *Journal of the Acoustical Society of America, 55*(5), 1100-1103.

Libes, S. M. (1992). *An Introduction to Marine Biogeochemistry* (pp. 734). New York, NY: John Wiley and Sons, Inc.

Loh, A. N. & Bauer, J. E. (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. doi: 10.1016/s0967-0637(00)00027-3

Lynn, R. J., Bograd, S. J., Chereskin, T. K. & Huyer, A. (2003). Seasonal renewal of the California Current: The spring transition off California. *Journal of Geophysical Research, 108*(C8), 3279. doi: 10.1029/2003JC001787

Madden, C. J., Goodin, K., Allee, R. J., Cicchetti, G., Moses, C., Finkbeiner, M. & Bamford, D. (2009). *Coastal and Marine Ecological Classification Standard - Version III*. (pp. 107) National Oceanic and Atmospheric Administration and NatureServe.

Mantua, N. & Hare, S. R. (2002). The Pacific decadal oscillation. *Journal of Oceanography, 58*, 35-44.

Marine Species Modeling Team. (2012). Determination of Acoustic Effects on Marine Mammals and Sea Turtles for the Atlantic Fleet Training and Testing Environmental Impact Statement/Overseas Environmental Impact Statement. (NUWC-NPT Technical Report 12,071) Naval Underseas Warfare Command Division, Newport.

Martin, J. H. & Gordon, M. R. (1988). Northeast Pacific iron distributions in relation to phytoplankton productivity. *Deep-Sea Research, 35*(2), 177-196. doi: 10.1016/0198-0149(88)90035-0

McDonald, M. A., Hildebrand, J. A., & Wiggins, S. M. (2006). Increases in deep ocean ambient noise in the Northeast Pacific west of San Nicolas Island, California.

McDonald, M. A., Hildebrand, J. A., Wiggins, S. M., & Ross, D. (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, 1985.

McLennan, M.W. (1997). A simple model for water impact peak pressure and width: a technical memorandum. Goleta, CA: Greeneridge Sciences Inc.

Millán-Núñez, R., Alvarez-Borrego, S. & Trees, C. C. (1997). Modeling the vertical distribution of chlorophyll in the California current system. *Journal of Geophysical Research, 102*(C4), 8587-8595.

Mintz, J. D. (2012). Vessel Traffic in the Hawaii-Southern California and Atlantic Fleet Testing and Training Study Areas

Mintz, J. D. & Filadelfo, R. J. (2011). Exposure of marine mammals to broadband radiated noise [Final Report]. (CRM D0024311.A2, pp. 36 pp.) CNA Corporation. Prepared by P. b. t. C. C. f. t. U. S. D. o. Defense.

Mintz, J. D. & Parker, C. L. (2006). *Vessel Traffic and Speed Along the U. S. Coasts and Around Hawaii* [Final report]. (CRM D0013236.A2, pp. 48). Alexandria, VA: CNA Corporation.

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. Retrieved from http://www.jstor.org/stable/2656218

National Marine Fisheries Service. (2008). *Biological Opinion for the 2008 Rim-of-the-Pacific Joint Training Exercises*. (pp. 301). 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 & U.S. Fish and Wildlife Service. (2009). Critical Habitat Data [Shapefile]. NOAA Fisheries Geographic Informaiton Systems. Silver Spring, MD. Available from http://www.nmfs.noaa.gov/gis/data/critical.htm, and http://www.fws.gov/plover/

National Oceanic and Atmospheric Administration. (2001). Office of Coast Survey. Retrieved from http://www.charts.noaa.gov/Catalogs/atlantic_chartside.shtml

National Oceanic and Atmospheric Administration. (2002). LME Polygon Boundaries, Offshore LME Boundaries [Shapefile]. LME Boundaries Download Page. Silver Spring, MD: Large Marine Ecosystem Program. Available from http://www.lme.noaa.gov/index.php?option=com_content&view=article&id=177&Itemid=75

National Oceanic and Atmospheric Administration. (2009). *National Oceanographic Data Center*. [Web Page]. Retrieved from http://www.nodc.noaa.gov, 06 May 2010.

National Oceanic Atmospheric Administration. (2010). *Large Marine Ecosystems of the World*. [Web Page]. Retrieved from http://www.lme.noaa.gov/index.php?option=com_content&view=article&id=47&Itemid=41, 06 May 2010.

National Research Council. (1990). *Monitoring Southern California's Coastal Waters* (pp. 15). Washington, D.C.: National Academy Press. Retrieved from Copyright protected.

National Research Council. (2003). Ocean Noise and Marine Mammals (pp. 219). Washington, DC: National Academies Press.

Navy Research Laboratory. (2011). Digital Bathymetry Data Base v 4.0. Retrieved from http://www7320.nrlssc.navy.mil/DBDB2_WWW/NRLCOM_dbdb2.html

Nemoto, K. & Kroenke, L. W. (1981). Marine Geology of the Hess Rise 1. Bathymetry, Surface Sediment Distribution, and Environment of Deposition. *Journal of Geophysical Research, 86*(B11), 10734-10752. doi: 10.1029/JB086iB11p10734

Norcross, B. L., McKinnell, S. M., Frandsen, M., Musgrave, D. L. & Sweet, S. R. (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, Exponent, Tricas, T. & Gill, A. (2011). Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species. Camarillo, CA: U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region. Available from http://www.gomr.boemre.gov/PI/PDFImages/ESPIS/4/5115.pdf

North Pacific Marine Science Organization. (2004). *Marine ecosystems of the North Pacific* [Electronic Version]. (PICES Special Publication 1, pp. 280) North Pacific Marine Science Organization. Available from http://www.pices.int/publications/special_publications/NPESR/2005/npesr_2005.aspx

Northrop, J. (1974). Detection of low-frequency underwater sounds from a submarine volcano in the Western Pacific. *Journal of the Acoustical Society of America*, 56(3), 837-841.

Pater, L. L. (1981). Gun blast far field peak overpressure contours. Naval Surface Weapons Center.

Payne, K. & Payne, R. (1985). Large scale changes over 19 years in songs of humpback whales in Bermuda. *Zeitschrift fur Tierpsychologie 68*, 89-114.

Pickard, G.L. & Emery, W.J. (1990). Descriptive Physical Oceanography: An Introduction (5th ed.). Oxford: Pergamon Press.

Pierce, A.D. (1989). Acoustics: An introduction to its physical principles and applications. Woodbury, NY: *Acoustical Society of America*.

Polefka, S. (2004). *Anthropogenic Noise and the Channel Islands National Marine Sanctuary: How Noise Affects Sanctuary Resources, and What We Can Do About It*. (pp. 51). Santa Barbara, CA: Environmental Defense Center. Available from Channel Islands National Marine Sanctuary website: http://www.channelislands.noaa.gov/sac/report_doc.html

Polovina, J. J., Haight, W. R., Moffitt, R. B. & Parrish, F. A. (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. Retrieved from http://www.jstor.org/stable/20105039

Polovina, J. J., Howell, E., Kobayashi, D. R. & Seki, M. P. (2001). The transition zone chlorophyll front, a dynamic global feature defining migration and forage habitat for marine resources. *Progress in Oceanography, 49*, 469-483.

Polovina, J. J., Mitchum, G. T., Graham, N. E., Craig, M. P., DeMartini, E. E. & Flint, E. N. (1994). Physical and biological consequences of a climate event in the central North Pacific. *Fisheries Oceanography, 3*(1), 15-21.

Qiu, B., Koh, D. A., Lumpkin, C. & Flament, P. (1997). Existence and Formation Mechanism of the North Hawaiian Ridge Current. *Journal of Physical Oceanography, 27*(3), 431-444. doi: 10.1175/1520-0485(1997)027<0431:EAFMOT>2.0.CO;2

Ramcharitar, J., Gannon, D. & Popper, A. (2006). Bioacoustics of fishes of the family Sciaenidae (croakers and drums). *Transactions of the American Fisheries Society, 135*, 1409-1431.

Rasmussen, M. H., Miller, L. A. & Au, W. W. L. (2002). Source levels of clicks from free-ranging white-beaked dolphins (*Lagenorhynchus albirostris* Gray 1846) recorded in Icelandic waters. *Journal of the Acoustical Society of America, 111*(2), 1122-1125.

Reeder, D. M. & Kramer, K. M. (2005, April). Stress in Free-Ranging Mammals: Integrating Physiology, Ecology, and Natural History. *Journal of Mammalogy, 86*(2), 225-235. Retrieved from http://www.jstor.org/stable/4094340?origin=JSTOR-pdf

Reid, J. L., Jr., Roden, G. I. & Wyllie, J. G. (1958). Studies of the California current system. *CalCOFI Report, 6*, 27-56.

Reverdin, G., Niiler, P. P. & Valdimarsson, H. (2003). North Atlantic Ocean surface currents. *Journal of Geophysical Research, 108*(C1), 3002-3023. doi: 10.1029/2001jc001020

Richardson, W. J., Greene, C. R., Malme, C. I. & Thomson, D. H. (1995). Marine Mammals and Noise: Academic Press.

Rooney, J., Wessel, P., Hoeke, R., Weiss, J., Baker, J., Parrish, F., Vroom, P. (2008). Geology and geomorphology of coral reefs in the northwestern Hawaiian Islands. In B. M. Riegl and R. E. Dodge (Eds.), *Coral Reefs of the USA. Coral Reefs of the World* (Vol. 1, pp. 515-567). Springer.

Santamaria-del-Angel, E., Millan-Nuñez, R., Gonzalez-Silvera, A. & Muller-Karger, F. (2002). The color signature of the Ensenada Front and its seasonal and interannual variability. *CalCOFI Report, 43*, 155-161.

Sherman, K. & Hempel, G. (2009). *The UNEP Large Marine Ecosystem Report: A Perspective on Changing Conditions in LMEs of the World's Regional Seas* [Electronic Version]. (UNEP Regional Seas Report and Studies No. 182). Nairobi, Kenya: United Nations Environmental Programme. Available from http://www.iwlearn.net/publications/regional-seas-reports/unep-regional-seas-reports-and-studies-no-182/

Sies, H. (1997). Oxidative stress: oxidants and antioxidants. *Exp Physiol*. 82, 291-295.

Simmonds, M., Dolman, S. J., Weilgart, L., Owen, D., Parsons, E. C. M., Potter, J. & Swift, R. J. (2003). Oceans of Noise *A WDCS Science Report*. Whale and Dolphin Conservation Society (WDCS),.

Slabbekoorn, H. and E. Ripmeester. (2008). "Birdsong and anthropogenic noise: implications and applications for conservation." Molecular Ecology 17(1): 72-83.

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene, C. R., Jr., Tyack, P. L. (2007). Marine mammal noise exposure criteria: initial scientific recommendations. [Journal Article]. *Aquatic Mammals, 33*(4), 411-521.

Spalding, M. D., Fox, H. E., Allen, G. R., Davidson, N., Ferdaña, Z. A., Finlayson, M., Roberston, J. (2007). Marine ecoregions of the world: A bioregionalisation of coastal and shelf areas. *Bioscience, 57*(7), 573-583.

Spargo, B. J. (2007, June 1). Chaff end cap and piston buoyancy. M. Collins, Parson.

St. Aubin, D. J. & Dierauf, L. A. (2001). Stress and Marine Mammals L. A. Dierauf and F. M. D. Gulland (Eds.), *Marine Mammal Medicine* (second ed., pp. 253-269). Boca Raton: CRC Press.

Swope, B. (2010). *Laser System Usage in the Marine Environment: Applications and Environmental Considerations*. (Technical Report 1996, pp. 47). San Diego: SPAWAR, Systems Center Pacific.

Talley, L. D. (1993). Distribution and formation of North Pacific intermediate water. *Journal of Physical Oceanography, 23*(3), 517-537. doi: 10.1175/1520-0485(1993)023<0517:DAFONP>2.0.CO;2

The White House Council on Environmental Quality. (2010). *Final Recommendations Of The Interagency Ocean Policy Task Force*. Available from http://www.whitehouse.gov/files/documents/OPTF_FinalRecs.pdf

Thompson, T. J., Winn, H. E. & Perkins, P. J. (1979). Mysticete sounds H. E. Winn and B. L. Olla (Eds.), *Behavior of Marine Animals* (Vol. 3: Cetaceans, pp. 403-431). New York: Plenum Press.

Tomczak, M. & Godfrey, J. S. (2003a). The Atlantic Ocean. In *Regional Oceanography: An Introduction* (2nd ed.). Daya Publishing House. Retrieved from http://www.es.flinders.edu.au/~mattom/regoc/pdfversion.html.

Tomczak, M. & Godfrey, J. S. (2003b). The Pacific Ocean. In *Regional Oceanography: An Introduction.* (2nd ed.). Daya Publishing House. Retrieved from http://www.es.flinders.edu.au/~mattom/regoc/pdfversion.html.

Tomczak, M. & Godfrey, J. S. (2003c). The Pacific Ocean. In *Regional Oceanography: An Introduction.* (2nd ed.). Daya Publishing House. Retrieved from http://www.es.flinders.edu.au/~mattom/regoc/pdfversion.html.

Touyz, R.M. (2004, September 1). Reactive Oxygen Species, Vascular Oxidative Stress, and Redox Signaling in Hypertension. *Hypertension*, 44(3), 248-252. 10.1161/01.HYP.0000138070.47616.9d Retrieved from http://hyper.ahajournals.org/content/44/3/248.

U.S. Air Force. (1997). Environmental Effects of Self-Protection Chaff and Flares. (pp. 241).

U.S. Army Corps of Engineers. (2012). U.S. Waterway Data. In *Waterborne Commerce of the United States*. Retrieved from http://www.ndc.iwr.usace.army.mil/data/datawcus.htm, March 29, 2012.

U.S Department of the Army. (1999). Finding of No Significant Impact (FONSI) for the Life Cycle Environmental Assessment (LCEA) for the HELLFIRE Modular Missile System.

U.S. Department of the Navy. (1996). *Environmental Assessment of the Use of Selected Navy Test Sites for Development Tests and Fleet Training Exercises of the MK-46 and MK 50 Torpedoes* [Draft report]. Program Executive Office Undersea Warfare, Program Manager for Undersea Weapons.

U.S. Department of the Navy. (2000). Noise Blast Test Results Aboard the USS Cole *Gun Blast Transmission into Water Test with a 5-Inch/54 Caliber Naval Gun (Standard Ordnance)*.

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. (2009). VACAPES Range Complex Environmental Impact Statement/Overseas Environmental Impact Statement. Final March 2009.

U.S. Department of the Navy. (2011). Marine Species Monitoring for the U.S. Navy's Hawaii Range Complex and the Southern California Range Complex. 2011 Annual Report. Available at www.nmfs.noaa.gov/pr/permits/incidental.htm#applications

U.S. Department of the Navy. (2012a). Pacific Navy Marine Species Density Database. Naval Facilities Engineering Command, Pacific. May 2012.

U.S. Department of the Navy. (2012b). Ecosystem Technical Report version 3 for the Atlantic Fleet Training and Testing (AFTT) Draft Environmental Impact Statement. (pp. 69) Naval Facilities Engineering Command Atlantic Division. Prepared by Tetra Tech Inc. Available from http://www.ttcollab.com/teammarine/Task%20Orders/Forms/AllItems.aspx?RootFolder=%2fteammarine%2fTask%20Orders%2fTO46%20Atlantic%20EIS%2fDeliverables%2fTask_7%2fDEIS%20v%2e3&FolderCTID=&View=%7b8D69BFE4-ED90-4BA7-BE65-F742CA308804%7d

Uchupi, E. & Emery, K. O. (1963). The continental slope between San Francisco, California and Cedros Island, Mexico. *Deep-Sea Research, 10*, 397-447.

Ulrich, R. (2004). *Development of a sensitive and specific biosensor assay to detect Vibrio vulnificus in estuarine waters.* (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. (2009a). *Global Open Oceans and Deep Seabed (GOODS) - Biogeographic Classification*. (IOC Technical Series, 84, pp. 95). Paris, France: UNESCO-IOC.

United Nations Educational Scientific and Cultural Organization. (2009b). *Global Open Oceans and Deep Seabed (GOODS) - Biogeographic Classification* (pp. 82). Paris, France: [IOC] Intergovernmental Oceanographic Comission.

University of Miami Rosenstiel School of Marine and Atmospheric Science & National Oceanic and Atmospheric Administration, National Oceanic Data Center. (2007). Global Annual Daytime Sea Surface Temperature (°C) - 2007 [GIS data]. *4 km AVHRR Pathfinder Version 5 SST Project (Pathfinder V5)*. Available from http://podaac.jpl.nasa.gov/DATA_CATALOG/avhrrinfo.html

Urick, R. J. (1983). Principles of Underwater Sound. Los Altos, CA: Peninsula Publishing.

Valiela, I. (1995). *Marine Ecological Processes* (2nd ed.). New York, NY: Springer-Verlag.

Vanderbilt Engineering Center for Transportation Operations and Research. (2004). National Waterway Network: U.S. Army Corps of Engineers Navigation Data Center; New Orleans, LA.

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., Smith, C. R. & De Leo, F. C. (2010). Hawaiian hotspots: enhanced megafaunal abundance and diversity in submarine canyons on the oceanic islands of Hawaii. *Marine Ecology 31*(1), 183-199. doi: 10.1111/j.1439-0485.2009.00351.x

Watkins, W. A. (1980). Acoustics and the behavior of Sperm Whales R. G. Busnel and J. F. Fish (Eds.), *Animal Sonar Systems* (pp. 283-290). New York: Plenum Press.

Wenz, G.M. (1962). Acoustic ambient noise in the ocean: Spectra and sources. *Journal of the Acoustical Society of America* 34:1936-1956.

Wolanski, E., Richmond, R. H., Davis, G., Deleersnijder, E. & Leben, R. R. (2003). Eddies around Guam, an island in the Mariana Islands group. *Continental Shelf Research, 23*(10), 991-1003. doi: 10.1016/s0278-4343(03)00087-6

Yagla, J. & Stiegler, R. (2003). Gun Blast Noise Transmission Across the Air-Sea Interface. Dahlgren, VA.

Young, G. A. (1991). Concise methods for predicting the effects of underwater explosions on marine life (pp. 1-12). Silver Spring: Naval Surface Warfare Center.

Young, R. W. (1973). Sound pressure in water from a source in air and vice versa. *Journal of the Acoustical Society of America, 53*(6), 1708-1716.

Zorn, H.M., Churnside, J.H. & Oliver, C.W. (2000). Laser safety thresholds for cetaceans and pinnipeds. *Marine Mammal Science*, 16(1): 186-200.

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