3 Affected Environment and Environmental Consequences

Supplemental Environmental Impact Statement/

Overseas Environmental Impact Statement

Mariana Islands Training and Testing

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3 Affected Environment and Environmental Consequences

This chapter describes the United States (U.S.) Department of the Navy's (Navy's) approach to analysis, existing environmental conditions in the Mariana Islands Training and Testing (MITT) 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 Mariana Islands Training and Testing Study Area) and depicted in Figure 2.1-1.

3.0 Introduction

In May 2015, the Navy released the MITT Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS) (U.S. Department of the Navy, 2015a), hereafter referred to as the 2015 MITT Final EIS/OEIS, for which a Record of Decision was released (U.S. Department of the Navy, 2015b). The Navy applied the Navy Acoustics Effects Model for the 2015 MITT Final EIS/OEIS to quantitatively analyze potential acoustic effects from Navy training and testing activities. For this Supplemental EIS (SEIS)/OEIS, the Navy refined the Navy Acoustics Effects Model (U.S. Department of the Navy, 2018b) and updated marine mammal density estimates (U.S. Department of the Navy, 2018a), as well as the acoustic criteria and activity data inputs used in the acoustic model (U.S. Department of the Navy, 2017c).

The following subsections are included in Section 3.0:

- Section 3.0.1 (Overall Approach to Analysis) identifies the methodology used in this SEIS/OEIS to assess resource impacts associated with the Proposed Action.
- Section 3.0.2 (Regulatory Framework) presents the regulatory framework on which this SEIS/OEIS is based. It identifies applicable laws, regulations, executive orders (EOs), and directives used to develop the analyses.
- Section 3.0.3 (Resources and Issues Not Carried Forward for More Detailed Discussion) identifies the resources that were eliminated from further consideration in this SEIS/OEIS.
- Section 3.0.4 (Identification of Stressors for Analysis) discusses the stressors used in the analysis of impacts on resources

3.0.1 Overall Approach to Analysis

The methods used in this SEIS/OEIS to assess resource impacts associated with the Proposed Action include the procedural steps outlined below:

- Review the existing 2015 MITT Final EIS/OEIS and Record of Decision.
- Determine if the affected environment has changed.
- Identify new activities and proposed changes to existing activities.
- Identify the stressors associated with the updated list of activities.
- Review existing and identify new federal and state regulations and standards relevant to resource-specific management or protection and determine if there has been any change since the 2015 MITT Final EIS/OEIS.
- Review and apply new literature, including science, surveys, and information on how resources could be affected by stressors.
- Determine if there is a new method of analysis for those activities.
- Review and consider comments received from members of the public and other stakeholders during the scoping period.

- Identify past, present, and reasonably foreseeable future actions to analyze the cumulative impacts.
- Consider mitigation measures to reduce identified potential impacts.

3.0.1.1 Navy Compiled and Generated Data

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

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

3.0.1.1.1 Marine Species Monitoring and Research Programs

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

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

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

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

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

3.0.1.2.1 Marine Species Density Database

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

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

The resulting Geographic Information System database includes seasonal density values for every marine mammal and sea turtle species present within the Study Area. This database is described in the technical report titled *U.S. Navy Marine Species Density Database Phase III for the Mariana Islands Training and Testing Study Area* (U.S. Department of the Navy, 2018a), hereafter referred to as the Density Technical Report. These data were used as an input into the Navy Acoustic Effects Model.

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

1. Spatial density models are preferred and used when available because they provide an estimate with the least amount of uncertainty by deriving estimates for divided segments of the sampling area. These models (see Becker et al., 2016; Forney et al., 2015) predict spatial variability of animal presence as a function of habitat variables (e.g., sea surface temperature, seafloor depth). This model is developed for areas, species, and, when available, specific timeframes (months or seasons) with sufficient survey data.
2. Stratified design-based density estimates use line-transect survey data with the sampling area divided (stratified) into sub-regions, and a density is predicted for each sub-region (see Barlow, 2016; Becker et al., 2016; Bradford et al., 2017; Campbell et al., 2015; Jefferson et al., 2014). While geographically stratified density estimates provide a good indication of a species' distribution within the Study Area, the uncertainty is typically high because each sub-region estimate is based on a smaller stratified segment of the overall survey effort.
3. Design-based density estimations use line-transect survey data from land and aerial surveys designed to cover a specific geographic area (see Carretta et al., 2015). These estimates use the same survey data as stratified design-based estimates, but they are not segmented into sub-regions and instead provide one estimate for a large surveyed area.
4. Although relative environmental suitability models provide estimates for areas of the oceans that have not been surveyed, using information on species occurrence and inferred habitat associations, and have been used in past density databases, these models were not used in the current quantitative analysis.

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

3.0.1.2.2 Developing Acoustic and Explosive Criteria and Thresholds

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

Since the release of the *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effect Analysis* in 2012 (U.S. Department of the Navy, 2012b), recent and emerging science has necessitated an update to these criteria and thresholds for assessing potential impacts on marine mammals and sea turtles. A detailed description of the Phase III acoustic and explosive criteria and threshold development is included in the supporting technical report *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Impact to Marine Mammals and Sea Turtles* (U.S. Department of the Navy, 2017c), and details are provided in each resource section. A series of behavioral studies, largely funded by the U.S. Navy, has led to a new understanding of how some species of marine mammals react to military sonar. This understanding resulted in developing new behavioral response functions for estimating alterations in behavior. Additional information on auditory weighting functions has also emerged [e.g., (Mulsow et al., 2015)], leading to the development of a new methodology to predict auditory weighting functions for each hearing group along with the accompanying hearing loss thresholds. These criteria for predicting hearing loss in marine mammals were largely adopted by NMFS for species within their purview (National Marine Fisheries Service, 2016).

The Navy also uses criteria for estimating effects to fishes and the ranges to which those effects are likely to occur. A working group of experts generated a technical report that provides numerical criteria and relative likelihood of effects to fish within different hearing groups (i.e., fishes with no swim bladder versus fishes with a swim bladder involved in hearing) (Popper et al., 2014). Where applicable, thresholds and relative risk factors presented in the technical report were used to assist in the analysis of effects to fishes from Navy activities. Details on criteria used to estimate impacts on marine fishes are contained within the appropriate stressor section (e.g., sonar and other transducers, explosives) within Section 3.9 (Fishes). This panel of experts also estimated parametric criteria for the effects of sea turtle exposure to sources located at ”near,” “intermediate,” and “far” distances, assigning ”low,” ”medium,” and “high” probability to specific categories of behavioral impacts (Popper et al., 2014).

3.0.1.2.3 The Navy’s Acoustic Effects Model

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

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

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

- Naval activities are modeled as though they would occur regardless of proximity to marine mammals or sea turtles (i.e., mitigation and implementation of standard operating procedures that employ protective measures are not modeled) and without any avoidance of the activity by the animal. The final step of the quantitative analysis of acoustic effects is to consider the implementation of mitigation. For sonar and other transducers, the possibility that marine mammals or sea turtles would avoid continued or repeated sound exposures is also considered.

- Many explosions from munitions such as bombs and missiles actually occur upon impact with above-water targets and at the water's surface. However, for this analysis, sources such as these were modeled as exploding underwater. This modeling overestimates the amount of explosive and acoustic energy entering the water.

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

3.0.1.2.4 Accounting for Mitigation

3.0.1.2.4.1 Sonar and Other Transducers

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

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

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

3.0.1.2.4.2 Explosions

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

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

3.0.1.2.5 Marine Mammal Avoidance of Sonar and other Transducers

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

3.0.2 Regulatory Framework

In accordance with the Council on Environmental Quality regulations that implement the requirements of the NEPA, other planning and environmental review procedures are integrated in this SEIS/OEIS to the fullest extent possible. Chapter 6 (Additional Regulatory Considerations) provides a status of compliance with the applicable environmental laws, regulations, and EOs that were considered in preparing this SEIS/OEIS (including those that may be secondary considerations in the resource evaluations).

The federal statutes and EOs considered in this SEIS/OEIS that were described in Section 3.0.1 (Regulatory Framework) of the 2015 MITT Final EIS/OEIS have not changed.

3.0.3 Resources and Issues Not Carried Forward for More Detailed Discussion

Considerations under EO 13045, *Protection of Children from Environmental Health Risks and Safety Risks*, were eliminated from further analysis 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 environmental health risks or safety risks to children.

3.0.4 Identification of Stressors for Analysis

Some of the stressors identified for consideration in this SEIS/OEIS in the analysis of resources have been refined from those considered in the 2015 MITT Final EIS/OEIS. The list of stressors analyzed in this SEIS/OEIS and changes from the 2015 MITT Final EIS/OEIS are shown in Table 3.0-1. Although the names of some stressors have changed, the analysis conducted on that stressor did not change. Where useful, an explanation of the change is provided in italics.

Table 3.0-1: Comparison of Stressors Analyzed

2015 MITT Final EIS/OEIS	*Supplemental EIS/OEIS*
Components and Stressors for Physical Resources	
Sediments and Water Quality Stressors	
• Explosives and explosive byproducts • Metals • Chemicals other than explosives • Other materials	• Explosives • Metals • Chemicals • Other materials
Air Quality Stressors	
• Criteria pollutants • Hazardous air pollutants	• Criteria pollutants • Hazardous air pollutants
Components and Stressors for Biological Resources	
Acoustic Stressors	
• Sonar and other active acoustic sources • Vessel noise • Aircraft noise • Weapons firing, launch, and impact noise • Underwater explosives • Swimmer defense airguns	• Sonar and other transducers • Vessel noise • Aircraft noise • Weapons noise • *("Underwater explosives" is moved to next category of "In-water explosions")* • *(Swimmer defense airguns are not proposed or analyzed in this SEIS/OEIS)*
Explosive Stressors	
(*In the 2015 MITT Final EIS/OEIS, Explosives were included under Acoustic Stressors*)	• In-water explosions • In-air explosions
Energy Stressors	
• Electromagnetic devices • Lasers	• In-air electromagnetic devices (*included under Electromagnetic Devices*) • In-water electromagnetic devices (*included under Electromagnetic Devices*) • Lasers

Table 3.0-1: Comparison of Stressors Analyzed (continued)

2015 MITT Final EIS/OEIS	*Supplemental EIS/OEIS*
Components and Stressors for Physical Resources	
Physical Disturbance and Strike Stressors	
• Aircraft and aerial targets • Vessels • In-water devices • Military expended materials • Seafloor devices • Ground disturbance • Wildfires	• Aircraft and aerial targets • Vessels and in-water devices • Military expended materials • Seafloor devices • Ground disturbance (FDM only) • Wildfires (FDM only)
Entanglement Stressors	
• Fiber optic cables and guidance wires • Decelerators/parachutes	• Wires and cables • Decelerators/parachutes
Ingestion Stressors	
• Military expended materials from munitions • Military expended materials other than munitions	• Military expended materials from munitions • Military expended materials other than munitions
Secondary Stressors	
• Habitat • Prey availability	• Impacts on habitat • Invasive species introductions into terrestrial habitats (FDM only) • Impacts on prey availability
Components and Stressors for Human Resources	
Cultural Resources Stressors	
• Acoustic • Physical Disturbance and Strike	• Explosives (*previously referred to as Acoustic*) • Physical Disturbance and Strike
Socioeconomic Resources Stressors	
• Accessibility • Airborne acoustics • Physical disturbance and strike • Secondary impacts from availability of resources	• Accessibility • Airborne acoustics • Physical disturbance and strike • Secondary impacts from availability of resources
Public Health and Safety Stressors	
• Underwater energy • In-air energy • Physical interactions • Secondary stressors (sediments and water quality)	• Underwater energy • In-air energy • Physical interactions • Secondary stressors (sediments and water quality)

Notes: (1) *Italics* reflect changes in stressors/stressor analysis in this SEIS/OEIS as compared to 2015 MITT Final EIS/OEIS; (2) FDM = Farallon de Medinilla

3.0.4.1 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 section provides the basis for analysis of acoustic impacts on resources in the remainder of Chapter 3 (Affected Environment and Environmental Consequences). Explanations of the terminology and metrics used when describing sound in this SEIS/OEIS are in Appendix H (Acoustic and Explosive Concepts).

Acoustic stressors include acoustic signals emitted into the water from a specific source such as sonar and other transducers (devices that convert energy from one form to another – in this case, to sound waves), as well as incidental sources of broadband sound produced as a byproduct of vessel movement, aircraft transits, and use of weapons or other deployed objects. Explosives also produce broadband sound but are characterized separately from other acoustic sources due to their unique hazardous characteristics (Section 3.0.4.2, Explosive Stressors). Characteristics of each of these sound sources are described in the following sections.

In order to better organize and facilitate the analysis of approximately 300 sources of underwater sound used for testing and training by the Navy including sonars, other transducers, and explosives, a series of source classifications, or source bins, were developed. The source classification bins do not include the broadband sounds produced incidental to vessel and aircraft transits and weapons firing.

The use of source classification bins provides the following benefits:

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

3.0.4.1.1 Sonar and Other Transducers

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

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

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

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

3.0.4.1.1.1 Anti-Submarine Warfare

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

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

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

3.0.4.1.1.2 Mine Warfare, Small Object Detection, and Imaging

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

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

3.0.4.1.1.3 Navigation and Safety

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

3.0.4.1.1.4 Communication

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

3.0.4.1.1.5 Classification of Sonar and Other Transducers

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

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

The bins used for classifying active sonars and transducers that are quantitatively analyzed in the Study Area are shown in Table 3.0-2. While general parameters or source characteristics are shown in the table, actual source parameters are classified.

Table 3.0-2 also shows the bin use that could occur in any year under each action alternative for training and testing activities and Phase II amounts are included for comparison.

Table 3.0-2: Sonar and Transducer Sources Quantitatively Analyzed

Source Class Category	*Bin*	*Unit**	*Training & Testing*		
			2015 Final EIS/OEIS	*Alternative 1*	*Alternative 2*
Low-Frequency (LF): Sources that produce signals less than 1 kHz	LF4	H	123	1	1
	LF5	H	11	10	10
	LF6	H	40	0	0
Mid-Frequency (MF): Tactical and non-tactical sources that produce signals between 1 and 10 kHz	MF1	H	1,872	1,729	1,818
	MF1K	H	0	3	3
	MF2	H	625	0	0
	MF3	H	192	189	228
	MF4	H	214	172	185
	MF5	C	2,588	2,024	2,094
	MF6	C	33	62	74
	MF8	H	123	0	0
	MF9	H	47	15	29
	MF10	H	231	0	0
	MF11	H	324	292	304
	MF12	H	656	608	616
High-Frequency (HF): Tactical and non-tactical sources that produce signals between 10 and 100 kHz	HF1	H	113	63	73
	HF3	H	0	4	4
	HF4	H	1,060	1,472	1,472
	HF5	H	336	0	0
	HF6	H	1,173	163	309
Anti-Submarine Warfare (ASW): Tactical sources (e.g., active sonobuoys and acoustic countermeasures systems) used during ASW training and testing activities	ASW1	H	144	192	192
	ASW2	C	660	538	554
	ASW3	H	3,935	3,024	3,124
	ASW4	C	11	268	332
	ASW5	H	0	50	50
Torpedoes (TORP): Source classes associated with the active acoustic signals produced by torpedoes	TORP1	C	115	62	71
	TORP2	C	62	40	62
	TORP3	C	0	6	6
Forward Looking Sonar (FLS): Forward or upward looking object avoidance sonars used for ship navigation and safety	FLS2	H	0	4	4
Acoustic Modems (M): Systems used to transmit data through the water	M3	H	112	17	31

Table 3.0-2: Sonar and Transducer Sources Quantitatively Analyzed (continued)

Source Class Category	*Bin*	*Unit**	*Training & Testing*		
			2015 Final EIS/OEIS	*Alternative 1*	*Alternative 2*
Swimmer Detection Sonar (SD): Used to detect divers and submerged swimmers	SD1	H	2,341	0	0
Air Guns (AG): Used during swimmer defense and diver deterrent training and testing activities	AG	C	308	0	0
Synthetic Aperture Sonars (SAS): Sonars in which active acoustic signals are post-processed to form high-resolution images of the seafloor	SAS2	H	0	449	449
	SAS4	H	0	6	6

* H = hours; C = count (e.g., number of individual pings or individual sonobuoys)

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

- Transmit primarily above 200 kHz: Sources above 200 kHz are above the hearing range of the most sensitive marine mammals and far above the hearing range of other protected species in the Study Area.
- Source levels of 160 dB re 1 µPa or less: Low-powered sources with source levels less than 160 dB re 1 µPa are typically hand-held sonars, range pingers, transponders, and acoustic communication devices. Assuming spherical spreading for a 160 dB re 1 µPa source, the sound will attenuate to less than 140 dB re 1 µPa within 10 m and less than 120 dB re 1 µPa within 100 m of the source. Ranges would be even shorter for a source less than 160 dB re 1 µPa source level.
- Acoustic source classes listed in Table 3.0-3: Sources with operational characteristics, such as short pulse length, narrow beam width, downward-directed beam, and low energy release, or manner of system operation, which exclude the possibility of any significant impact on a protected species (actual source parameters are classified). Even if there is a possibility that some species may be exposed to and detect some of these sources, any response is expected to be short-term and inconsequential.

Table 3.0-3: Sonar and Transducers Qualitatively Analyzed

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

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

3.0.4.1.2 Vessel Noise

Vessel noise, in particular commercial shipping, is a major contributor to underwater anthropogenic noise in the ocean within the Study Area. Naval vessels (e.g., ships and small craft) and civilian vessels (e.g., commercial ships, tugs, work boats, pleasure craft) produce low-frequency, broadband underwater sound, though the exact level of noise produced varies by vessel type. Frisk (2012) reported that between 1950 and 2007 ocean noise in the 25–50 Hertz (Hz) frequency range has increased 3.3 dB per decade, resulting in a cumulative increase of approximately 19 dB over a baseline of 52 dB. The increase in noise is associated with an increase in commercial shipping, which correlates with global economic growth (Frisk, 2012). Within the Study Area, Navy vessels represent a small amount of overall vessel traffic and an even smaller amount of overall vessel traffic noise (Mintz & Filadelfo, 2011; Mintz, 2012).

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

Although the aforementioned studies did not include analysis of vessel traffic and associated vessel noise in the Study Area (the geographic scope was the continental United States and Hawaii), the conclusions of the studies are relevant to vessel noise in the Study Area. Overall, the contribution of Navy vessel traffic to broadband noise levels was relatively small compared with the contribution from commercial vessel traffic.

The 2015 MITT Final EIS/OEIS (Section 3.0.5.2.1.5, Vessel Noise) provides detailed information regarding vessel noise characteristics and production, and timing and duration of vessel activity.

3.0.4.1.3 Aircraft Noise

Fixed-wing, tiltrotor, and rotary-wing aircraft are used for a variety of training and testing activities throughout the Study Area, contributing both airborne and underwater sound to the ocean environment. Sounds in air are often measured using A-weighting, which adjusts received sound levels based on human hearing abilities (see Appendix H, Acoustic and Explosive Concepts). Aircraft used in training and testing generally have turboprop or jet engines. Motors, propellers, and rotors produce the most noise, with some noise contributed by aerodynamic turbulence. Aircraft sounds have more energy at lower frequencies. Aircraft may transit to or from vessels at sea throughout the Study Area from established airfields on land. The majority of aircraft noise would be generated at air stations, which are outside the Study Area. Takeoffs and landings occur at established airfields as well as on vessels at sea across the Study Area. Takeoffs and landings from Navy vessels produce in-water noise at a given location for a brief period as the aircraft climbs to cruising altitude. Military activities involving aircraft generally are dispersed over large expanses of open ocean but can be highly concentrated in time and location. Table 3.0-4 provides source levels for some typical aircraft used during training and testing in the Study Area and depicts comparable airborne source levels for the F-35A, EA-18G, and F/A-18C/D during takeoff.

3.0.4.1.3.1 Underwater Transmission of Aircraft Noise

The 2015 MITT Final EIS/OEIS (Section 3.0.5.2.1.6, Aircraft Overflight Noise) describes underwater transmission of aircraft noise. Since information regarding underwater transmission of aircraft noise has not changed, this SEIS/OEIS will not further analyze underwater transmission of aircraft noise.

3.0.4.1.3.2 Helicopters

The 2015 MITT Final EIS/OEIS (Section 3.0.5.2.1.6, Aircraft Overflight Noise) describes characteristics and production of noise from helicopters. Since information regarding characteristics and production of noise from helicopters has not changed, this SEIS/OEIS will not further analyze characteristics and production of noise from helicopters.

Table 3.0-4: Representative Aircraft Sound Characteristics

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

Notes: dB re 1 µPa = decibel(s) referenced to 1 micropascal, dBA re 20 µPa = A-weighted decibel(s) referenced to 20 micropascals, m = meter(s), ft. = feet, dBA re 20 $\mu Pa^2 s$ = A-weighted decibel(s) referenced to 20 micropascals squared seconds
Sources: [1]Eller and Cavanagh (2000), [2]Bousman and Kufeld (2005), [3]U.S. Naval Research Advisory Committee (2009), [4]U.S. Department of the Air Force (2016), [5]U.S. Department of the Navy (2012a).

3.0.4.1.3.3 Sonic Booms

An intense but infrequent type of aircraft noise is the sonic boom, produced when an aircraft exceeds the speed of sound. An intense but infrequent type of aircraft noise is the sonic boom, produced when an aircraft exceeds the speed of sound. Per Navy Instruction *Naval Air Training and Operating Procedures General Flight and Operating Instructions Manual, Commander Naval Air Forces Manual-3710.7* (U.S. Department of the Navy, 2017a), it is incumbent on every pilot flying aircraft capable of generating sonic booms to reduce such disturbances and damage to the absolute minimum dictated by operational/training requirements. Supersonic flight operations shall be strictly controlled and supervised by operational commanders. Supersonic flight over land or within 30 NM offshore shall be conducted in specifically designated areas. Such areas must be chosen to ensure minimum possibility of disturbance. As a general policy, sonic booms shall not be intentionally generated below 30,000 ft. of altitude unless over water and more than 30 miles from inhabited land areas or islands. Deviations from the foregoing general policy may be authorized only under one of the following conditions:

- tactical missions that require supersonic speeds;
- phases of formal training syllabus flights requiring supersonic speeds;
- research, test, and operational suitability test flights requiring supersonic speeds; or
- when specifically authorized by the Chief of Naval Operations for flight demonstration purposes.

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

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

In air, the energy from a sonic boom is concentrated in the frequency range from 0.1 to 100 Hz. The underwater sound field due to transmitted sonic boom waveforms is primarily composed of low-frequency components (Sparrow, 2002), and frequencies greater than 20 Hz have been found to be difficult to observe at depths greater than 33 ft. (10 meters) (Sohn et al., 2000). 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 (U.S. Department of the Air Force, 2000). Table 3.0-5 shows these results.

Table 3.0-5: Sonic Boom Underwater Sound Levels Modeled for F/A-18 Hornet Supersonic Flight

*Mach Number**	*Aircraft Altitude (km)*	*Peak SPL (dB re 1 µPa)*			*Energy Flux Density (dB re 1 µPa²-s)[1]*		
		At surface	*50 m Depth*	*100 m Depth*	*At surface*	*50 m Depth*	*100 m Depth*
1.2	1	176	138	126	160	131	122
	5	164	132	121	150	126	117
	10	158	130	119	144	124	115
2	1	178	146	134	161	137	128
	5	166	139	128	150	131	122
	10	159	135	124	144	127	119

[1] Equivalent to SEL for a plane wave.
* Mach number equals aircraft speed divided by the speed of sound.
Notes: SPL = sound pressure level, dB re 1 µPa = decibel(s) referenced to 1 micropascal, dB re 1 µPa²-s = decibel(s) referenced to 1 micropascal squared seconds, m = meter(s)

3.0.4.1.4 Weapon Noise

The Navy trains and tests using a variety of weapons, as described in Appendix A (Training and Testing Activities Descriptions). Depending on the weapon, incidental (unintentional) noise may be produced at launch or firing, while in flight, or upon impact. Other devices intentionally produce noise to serve as a non-lethal deterrent. Not all weapons utilize explosives, either by design or because they are non-explosive practice munitions. Noise produced by explosives, both in air and water, are discussed in Section 3.0.4.2 (Explosive Stressors).

Noise associated with large-caliber weapons firing and the impact of non-explosive practice munitions or kinetic weapons would occur at locations greater than 12 NM from shore in warning areas or special use airspace for safety reasons, with the exception of areas near Farallon de Medinilla (FDM). Small- and medium-caliber weapons firing could occur throughout the Study Area in identified training areas.

Table 3.0-6 shows examples of some types of weapons noise and provides examples of launch noise. Noise produced by other weapons and devices are described further below.

Table 3.0-6: Example Weapons Noise

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

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

3.0.4.1.4.1 Muzzle Blast from Naval Gunfire

The 2015 MITT Final EIS/OEIS (Section 3.0.5.2.1.4, Weapons Firing, Launch, and Impact Noise) describes the characteristics of the 5-inch (in.) large caliber naval gun, which is the most prevalent large weapon fired. Since information regarding characteristics of muzzle blast from naval gunfire has not changed, this SEIS/OEIS will not further analyze muzzle blast from naval gunfire. Examples of noise measurements from naval gunfire muzzle blast are provided in Table 3.0-6.

3.0.4.1.4.2 Supersonic Projectile Bow Shock Wave

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

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

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

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

3.0.4.1.4.3 Launch Noise

The 2015 MITT Final EIS/OEIS (Section 3.0.5.2.1.4, Weapons Firing, Launch, and Impact Noise) describes launch noise. Since information regarding launch noise has not changed, this SEIS/OEIS will not further analyze launch noise. Table 3.0-6 provides examples of launch noise measurements.

3.0.4.1.4.4 Impact Noise (Non-Explosive)

The 2015 MITT Final EIS/OEIS (Section 3.0.5.2.1.4, Weapons Firing, Launch, and Impact Noise) describes characteristics and production of non-explosive impact noise. Since information regarding non-explosive impact noise has not changed, this SEIS/OEIS will not further analyze non-explosive impact noise.

3.0.4.1.4.5 Long Range Acoustic Device

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

3.0.4.2 Explosive Stressors

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

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

3.0.4.2.1.1 Explosions in Water

Explosive detonations during training and testing activities are associated with high-explosive munitions, including, but not limited to, bombs, missiles, rockets, naval gun shells, torpedoes, mines, demolition charges, and explosive sonobuoys. Explosive detonations during training and testing activities involving the use of high-explosive munitions, including bombs, missiles, and naval gun shells, could occur in the air or near the water's surface. Explosive detonations associated with torpedoes and explosive sonobuoys would occur in the water column; mines and demolition charges could be detonated in the water column or on the ocean bottom. Detonations would typically occur in waters greater than 200 ft. in depth, and greater than 3 NM from shore, with the exception of existing mine warfare areas, including Outer Apra Harbor, Piti, and Agat. Section 5.3.3 (Explosive Stressors) outlines the procedural mitigation measures for explosive stressors to reduce potential impacts on biological resources.

In order to better organize and facilitate the analysis of Navy training and testing activities using explosives that could detonate in water or at the water surface, explosive classification bins were developed. The use of explosive classification bins provides the same benefits as described for acoustic source classification bins in Section 3.0.4.1 (Acoustic Stressors).

Explosives detonated in water are binned by net explosive weight. The bins of explosives that are proposed for use in the Study Area are shown in Table 3.0-7. This table shows the number of explosive items that could be used in any year under each action alternative for training and testing activities. A range of annual bin use indicates that use of that bin is anticipated to vary annually, consistent with the variation in the number of annual activities described in Chapter 2 (Description of Proposed Action and Alternatives).

In addition to the explosives quantitatively analyzed for impacts on protected species shown in Table 3.0-7, the Navy uses some very small impulsive sources (less than 0.1 pounds net explosive weight), categorized in bin E0, that are not anticipated to result in takes of protected species. Quantitative modeling in multiple locations has validated that these sources have a very small zone of influence. These E0 charges, therefore, are categorized as *de minimis* sources and are qualitatively analyzed to determine the appropriate determinations under NEPA in the appropriate resource impact analyses, as well as under the MMPA and the ESA.

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

Table 3.0-7: Explosive Sources Quantitatively Analyzed that Could Be Used Underwater or at the Water Surface

Explosives	***Training & Testing Activities (Annual In-Water Detonations)***		
	2015 Final EIS/OEIS	***Alternative 1***	***Alternative 2***
E1 (0.1–0.25 lb. NEW)	10,140	512	768
E2 (>0.25–0.5 lb. NEW)	106	400	400
E3 (>0.5–2.5 lb. NEW)	932	683	683
E4 (> 2.5–5 lb. NEW)	420	44	44
E5 (> 5–10 lb. NEW)	684	965	1,221
E6 (> 10–20 lb. NEW)	76	29	29
E8 (> 60–100 lb. NEW)	16	132–134	132–134
E9 (> 100–250 lb. NEW)	4	110	110
E10 (> 250–500 lb. NEW)	12	69	78
E11 (> 500–650 lb. NEW)	6	1–3	1–5
E12 (> 650–1,000 lb. NEW)	184	48	48

Notes: lb. = pound(s), NEW = Net Explosive Weight

3.0.4.2.1.2 Explosions in Air

Explosions in air include detonations of projectiles and missiles during surface-to-air gunnery and air-to-air missile exercises conducted during air warfare. These explosions typically occur far above the water surface in special use airspace. Some typical types of explosive munitions that would be detonated in air during Navy activities are shown in Table 3.0-8. Various missiles, rockets, and medium- and large-caliber projectiles may be explosive or non-explosive, depending on the objective of the training or testing activity in which they are used. Quantities of explosive and non-explosive missiles, rockets, and projectiles proposed for use during Navy training and testing are provided in the tables below.

Table 3.0-8: Typical Air Explosive Munitions During Navy Activities

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

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

Bombs and projectiles that detonate at or near the water surface, which are considered for underwater impacts (see Table 3.0-8), would also release some explosive energy into the air. Appendix A (Training and Testing Activities Descriptions) describes where activities with these stressors typically occur.

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

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

3.0.4.3 Energy Stressors

Energy stressors are discussed in the 2015 MITT Final EIS/OEIS. Changes to energy stressors analyzed in this SEIS/OEIS are described below.

3.0.4.3.1 Electromagnetic Devices

In the 2015 MITT Final EIS/OEIS, electromagnetic devices included those used in water. For this SEIS/OEIS, electromagnetic devices are further categorized as either in-water electromagnetic devices or in-air electromagnetic devices.

3.0.4.3.1.1 In-Water Electromagnetic Devices

In-water electromagnetic devices were described in Section 3.0.5.2.2.1 (Electromagnetic Devices) of the 2015 MITT Final EIS/OEIS. Table 3.0-9 shows the number of ongoing events (from the 2015 MITT Final EIS/OEIS) and the number of events proposed in this SEIS/OEIS that include the use of in-water electromagnetic devices.

Table 3.0-9: Annual Number of Events in the Study Area Including In-Water Electromagnetic Devices

Training & Testing		
2015 Final EIS/OEIS	***Alternative 1***	***Alternative 2***
5	4	4

3.0.4.3.1.2 In-Air Electromagnetic Devices

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

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

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

It is assumed that most Navy platforms associated with the Proposed Action will be transmitting from a variety of in-air electromagnetic devices at all times when underway, with very limited exceptions. Most of these transmissions (e.g., for routine surveillance, communications, and navigation) will be at low power. High-power settings are used for a small number of activities, including ballistic missile defense training, radar and other system testing, and signature analysis operations. The number of Navy vessels or aircraft in the Study Area at any given time varies and is dependent on local training or testing requirements. Therefore, in-air electromagnetic energy as part of the Proposed Action would be widely dispersed throughout the Study Area, but more concentrated in portions of the Study Area near ports, naval installations, and range complexes. Because these stressors are operated at power levels, altitudes, and distances from people and animals to ensure that energy received is well below levels that could disrupt behavior or cause injury and because most in-air electromagnetic energy is reflected by water, in-air electromagnetic energy is not analyzed further in Section 3.4 (Marine Mammals) and Section 3.6 (Marine Birds).

3.0.4.3.2 Lasers

Laser devices can be organized into two categories: (1) low-energy lasers and (2) high-energy lasers.

3.0.4.3.2.1 Low-Energy Lasers

Low-energy lasers are proposed to be used as described in the 2015 MITT Final EIS/OEIS, where they would have an extremely low potential to impact marine biological resources (U.S. Department of the Navy, 2010). Therefore, as in the 2015 MITT Final EIS/OEIS, low-energy lasers will not be further analyzed in this SEIS/OEIS for possible impacts on biological resources.

3.0.4.3.2.2 High-Energy Lasers

While no high-energy lasers were proposed to be used in the Study Area previously, they are now proposed for use as part of the Proposed Action in this SEIS/OEIS. High-energy laser weapons testing involves the use of directed energy as a weapon against small surface vessels and airborne targets. High-energy lasers would be employed from surface ships and are designed to create small but critical failures in potential targets. The high-energy laser is expected to be used at short ranges. Marine life or birds at or near the ocean surface could be susceptible to injury by high-energy lasers. Table 3.0-10 shows the number of ongoing events (from the 2015 MITT Final EIS/OEIS) and the number of events proposed in this SEIS/OEIS that include the use of high-energy lasers.

Table 3.0-10: Annual Number of Events in the Study Area Including High-Energy Lasers

Training & Testing		
2015 Final EIS/OEIS	***Alternative 1***	***Alternative 2***
0	54	60

3.0.4.4 Physical Disturbance and Strike Stressors

As described in the 2015 MITT Final EIS/OEIS, physical disturbance and strike stressors can result from the Navy's proposed use of aircraft and aerial targets, vessels, in-water devices, military expended materials, seafloor devices, and, on the island of FDM, ground disturbance and wildfires.

3.0.4.4.1 Aircraft and Aerial Targets

Section 3.0.5.2.3.1 (Aircraft and Aerial Targets) in the 2015 MITT Final EIS/OEIS described aircraft and aerial targets. Table 3.0-11 shows the number of ongoing events (from the 2015 MITT Final EIS/OEIS) and the number of events proposed in this SEIS/OEIS that include the use of aircraft.

Table 3.0-11: Annual Number of Events in the Study Area Including Aircraft Movement

Training & Testing		
2015 Final EIS/OEIS	***Alternative 1***	***Alternative 2***
22,397	20,058	20,094

3.0.4.4.2 Vessels

Section 3.0.5.2.3.2 (Vessels) in the 2015 MITT Final EIS/OEIS described vessels. Table 3.0-12 shows the number of ongoing events (from the 2015 MITT Final EIS/OEIS) and the number of events proposed in this SEIS/OEIS that include the use of vessels.

Table 3.0-12: Annual Number of Events in the Study Area Including Vessel Movement

Training & Testing		
2015 Final EIS/OEIS	***Alternative 1***	***Alternative 2***
3,968	4,249	4,493

3.0.4.4.3 In-Water Devices

Section 3.0.5.2.3.3 (In-Water Devices) in the 2015 MITT Final EIS/OEIS described in-water devices. Table 3.0-13 shows the number of ongoing events (from the 2015 MITT Final EIS/OEIS) and the number of events proposed in this SEIS/OEIS that include the use of towed in-water devices.

Table 3.0-13: Annual Number of Events in the Study Area Including In-Water Devices

Training & Testing		
2015 Final EIS/OEIS	***Alternative 1***	***Alternative 2***
2,205	2,289	2,397

3.0.4.4.4 Military Expended Materials

Section 3.0.5.2.3.4 (Military Expended Materials) in the 2015 MITT Final EIS/OEIS described military expended materials. Table 3.0-14 shows the number of non-explosive practice munitions analyzed in the 2015 MITT Final EIS/OEIS and the number proposed in this SEIS/OEIS. Other military expended materials are listed in Table 3.0-15, explosive munitions in Table 3.0-16, and targets in Table 3.0-17.

Table 3.0-14: Annual Number of Non-Explosive Practice Munitions Expended At Sea in the Study Area

Non-Explosive Ordnance	*Training & Testing*		
	2015 Final EIS/OEIS	***Alternative 1***	***Alternative 2***
Mine Neutralization System Neutralizers	24	0	0
Anti-Torpedo Torpedoes	N/A[1]	8	11
Torpedoes[2]	169	104	132

Table 3.0-14: Annual Number of Non-Explosive Practice Munitions Expended At Sea in the Study Area (continued)

Non-Explosive Ordnance	*Training & Testing*		
	2015 Final EIS/OEIS	*Alternative 1*	*Alternative 2*
Bombs	848	368	368
Rockets	0	1,697	1,697
Rockets (Flechette)	Note 1	89	89
Missiles	20	0	0
Kinetic Energy Rounds	Note 1	80	180
Large-Caliber Projectiles	6,918	14,772	22,268
Large-Caliber Projectile Land-Based Casings	Note 1	2,800	4,200
Medium-Caliber Projectiles	87,540	223,150	280,750
Small-Caliber Projectiles	88,140	308,364	354,318

Note 1: These items were not calculated in the 2015 Final EIS/OEIS.

Table 3.0-15: Annual Number of Other Military Expended Materials Used At Sea in the Study Area

Other Military Expended Materials	*Training & Testing*		
	2015 Final EIS/OEIS	*Alternative 1*	*Alternative 2*
Acoustic Countermeasures	294	387	466
Anchor (Expended)	Note 1	20	28
Anti-Torpedo Torpedo Accessories	Note 1	8	11
Buoy (Non-Explosive)	314	70	82
Canister – Miscellaneous	Note 1	1	1
Compression Pad or Plastic Pistons	Note 1	17,600	17,600
Endcap – Chaff and Flares	Note 1	35,218	35,218
Expended Bathythermograph	520	341	364
Fiber Optic Can	28	44	44
Flare O-ring	Note 1	17,618	17,618
Heavyweight Torpedo Accessories	54	49	73
Lightweight Torpedo Accessories	72	60	66
Illumination Flare	18	18	18
JATO Bottle	20	20	20

Table 3.0-15: Annual Number of Other Military Expended Materials Used At Sea in the Study Area (continued)

Other Military Expended Materials	Training & Testing		
	2015 Final EIS/OEIS	Alternative 1	Alternative 2
Marine Marker	617	538	538
Sonobuoys	11,912	5,386	5,876

Note 1: These items were not calculated in the 2015 Final EIS/OEIS.

Table 3.0-16: Annual Number of Explosive Munitions Expended At Sea in the Study Area

Explosive Ordnance	Training & Testing		
	2015 Final EIS/OEIS	Alternative 1	Alternative 2
Mine Neutralization System Neutralizers	28	44	44
Grenades	Note 1	400	400
Torpedoes	10	5	7
Bombs	212	198	198
Rockets	114	323	323
Missiles	145	231	249
Large-Caliber Projectiles	12,220	1,372	1,658
Medium-Caliber Projectiles	10,190	22,224	22,480
Buoys	804	392	392

Note 1: These items were not calculated in the 2015 Final EIS/OEIS.

Table 3.0-17: Annual Number of Targets Expended At Sea in the Study Area

Target	Training & Testing		
	2015 Final EIS/OEIS	Alternative 1	Alternative 2
Air Targets –Decoy	Note 1	153	168
Air Targets –Drone	Note 1	1	1
Mine Shape (Non-Explosive)	Note 1	599	599
Ship Hulk	2	1	1
Subsurface Target (Mobile)	Note 1	254	265
Subsurface Target (Stationary)	Note 1	4	5
Surface Target (Mobile)	Note 1	1,499	1,581
Surface Target (Stationary)	786	879	1,107

Note 1: These items were not calculated in the 2015 Final EIS/OEIS.

3.0.4.4.5 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, and bottom placed instruments. In certain cases, weights that anchor a device would be expended when the device is recovered (e.g., pop up buoys). 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). Table 3.0-18 shows the number of ongoing events (from the 2015 MITT Final EIS/OEIS) and the number of events proposed in this SEIS/OEIS that include the use of seafloor devices.

Table 3.0-18: Annual Number of Events in the Study Area Including Seafloor Devices

Training & Testing		
2015 Final EIS/OEIS	***Alternative 1***	***Alternative 2***
200	180	182

3.0.4.4.6 Ground Disturbance and Wildfires

Section 3.0.5.2.3.6 (Ground Disturbance and Wildfires) in the 2015 MITT Final EIS/OEIS described ground disturbance and wildfires on FDM. Table 3.0-19 shows the number and type of munitions analyzed in the 2015 MITT Final EIS/OEIS and proposed in this SEIS/OEIS.

Table 3.0-19: Annual Number of Munitions Used on Farallon de Medinilla

Ordnance Use	***2015 Final EIS/OEIS***	***Alternative 1***	***Alternative 2***
Small-caliber Rounds	42,000	44,096	44,096
NEPM Bombs ≤ 2,000 lb.	2,670	2,670	2,670
Explosive Bombs ≤ 2,000 lb.	6,242	6,242	6,242
Explosive Missiles and Rockets ≤ 5"	85 missiles; 2,000 rockets	115 missiles; 2,000 rockets	115 missiles; 2,000 rockets
Explosive Grenades and Mortars	600	1,000	1,000
Medium-caliber Projectiles	17,350 explosive; 94,150 NEPM	18,144 explosive; 94,150 NEPM	18,144 explosive; 94,150 NEPM
Large-caliber Projectiles	1,200 explosive; 1,800 NEPM	400 explosive	400 explosive

Notes: lb. = pound, NEPM = Non-Explosive Practice Munition

3.0.4.5 Entanglement Stressors

As described in the 2015 MITT Final EIS/OEIS, entanglement stressors can result from the Navy's proposed use of fiber optic cables, guidance wires, and decelerators/parachutes. In addition, sonobuoy wires, not previously identified as entanglement stressors, can be entanglement stressors and are included in this SEIS/OEIS for analysis.

3.0.4.5.1 Wires and Cables

3.0.4.5.1.1 Fiber Optic Cables

Although a portion may be recovered, some fiber optic cables used during Navy training and testing associated with remotely operated mine neutralization activities would be expended. The length of the expended tactical fiber would vary (up to about 3,000 meters) depending on the activity. Tactical fiber has an 8-micrometer (0.008 millimeter [mm]) silica core and acrylate coating, and looks and feels like thin monofilament fishing line. Other characteristics of tactical fiber are a 242-micrometer (0.24 mm) diameter, 12-pound tensile strength, and 3.4-mm bend radius (Corning Incorporated, 2005; Raytheon Company, 2015). Tactical fiber is relatively brittle; it readily breaks if knotted, kinked, or abraded against a sharp object. Deployed tactical fiber will break if looped beyond its bend radius (3.4 mm), or exceeds its tensile strength (12 pounds). If the fiber becomes looped around an underwater object or marine animal, it will not tighten unless it is under tension. Such an event would be unlikely based on its method of deployment and its resistance to looping after it is expended. The tactical fibers are often designed with controlled buoyancy to minimize the fiber's effect on vehicle movement. The tactical fiber would be suspended within the water column during the activity, and then be expended and sink to the seafloor (effective sink rate of 1.45 centimeters/second (Raytheon Company, 2015)) where it would be susceptible to abrasion and burial by sedimentation.

3.0.4.5.1.2 Guidance Wires

Section 3.0.5.2.4.1 (Guidance Wires) in the 2015 MITT Final EIS/OEIS described guidance wires.

3.0.4.5.1.3 Sonobuoy Wires

Sonobuoys consist of a surface antenna and float unit and a subsurface hydrophone assembly unit. The two units are attached through a thin-gauge, dual-conductor, and hard-draw copper strand wire, which is then wrapped by a hollow rubber tubing or bungee in a spiral configuration. The tensile breaking strength of the wire and rubber tubing is no more than 40 pounds. The length of the wire is housed in a plastic canister dispenser, which remains attached upon deployment. The length of wire that extends out is no more than 1,500 ft. and is dependent on the water depth and type of sonobuoy. Attached to the wire is a kite-drogue and damper disk stabilizing system made of non-woven nylon fabric. The nylon fabric is very thin and can be broken by hand. The wire runs through the stabilizing system, and leads to the hydrophone components. The hydrophone components may be covered by thin plastic netting depending on type of sonobuoy, but pose no entanglement risk. Each sonobuoy has a saltwater activated polyurethane float that inflates when the sonobuoy is submerged and keeps the sonobuoy components floating vertically in the water column below it. Sonobuoys remain suspended in the water column for no more than 30 hours, after which they sink to the seafloor.

Bathythermographs are similar to sonobuoys in that they consist of a subsurface unit (to measure temperature of the water column in the case of the bathythermograph) that is connected by wire to the float unit (for air-deployed bathythermographs) or directly to the ship (for ship-deployed bathythermographs). The bathythermograph wire is similar to the sonobuoy wire as described above.

Table 3.0-20 shows the number of wires and cables analyzed in the 2015 MITT Final EIS/OEIS and the number proposed in this SEIS/OEIS.

Table 3.0-20: Annual Number of Wires and Cables Expended in the Study Area

Training & Testing		
2015 Final EIS/OEIS	***Alternative 1***	***Alternative 2***
Fiber Optic Cables		
144	44	44
Guidance Wires		
60	49	73
Sonobuoy Wires		
Note 1	5,386	5,876
Bathythermograph Wires		
Note 1	341	364

Note 1: These items were not calculated in the 2015 Final EIS/OEIS.

3.0.4.5.2 Decelerators/Parachutes

Decelerators/parachutes used during training and testing activities are classified into four different categories based on size: small, medium, large, and extra-large (Table 3.0-21). Aircraft-launched sonobuoys and lightweight torpedoes (such as the MK 46 and MK 54) use nylon decelerators/parachutes ranging in size from 18 to 48 in. in diameter (small). The majority of the decelerators/parachutes in the small size category are smaller (18 in.) cruciform shape decelerators/parachutes associated with sonobuoys (Figure 3.0-1). Illumination flares use medium decelerators/parachutes, up to approximately 19 ft. in diameter. Both small- and medium-sized decelerators/parachutes are made of cloth and nylon, many with weights attached to their short attachment lines to speed their sinking. At water impact, the decelerator/parachute assembly is expended and sinks away from the unit. The decelerator/parachute assembly may remain at the surface for 5–15 seconds before the decelerator/parachute and its housing sink to the seafloor, where it becomes flattened (Environmental Sciences Group, 2005). Once settled on the bottom the canopy may temporarily billow if bottom currents are present.

Table 3.0-21: Size Categories for Decelerators/Parachutes Expended During Training and Testing Activities

Size Category	*Diameter (ft.)*	*Associated Activity*
Small	1.5–6	Air-launched sonobuoys, lightweight torpedoes, and drones (drag decelerator/parachute)
Medium	19	Illumination flares
Large	30–50	Drones (main decelerator/parachute)
Extra-large	82	Drones (main decelerator/parachute)

Figure 3.0-1: Sonobuoy Launch Depicting the Relative Size of a Small Decelerator/Parachute

Aerial targets (drones) use large (between 30 and 50 ft. in diameter) and extra-large (82 ft. in diameter) decelerators/parachutes (Figure 3.0-2). Large and extra-large decelerators/parachutes are also made of cloth and nylon, with suspension lines of varying lengths (large: 40–70 ft. in length [with up to 28 lines per decelerator/parachute]; extra-large: 82 ft. in length [with up to 64 lines per decelerator/parachute]). Some aerial targets also use a small drag parachute (6 ft. in diameter) to slow their forward momentum prior to deploying the larger primary decelerator/parachute. Unlike the small- and medium-sized decelerators/parachutes, drone decelerators/parachutes do not have weights attached and may remain at the surface or suspended in the water column for some time prior to eventual settlement on the seafloor.

Figure 3.0-2: Aerial Target (Drone) with Parachute Deployed

Table 3.0-22 shows the number of decelerators/parachutes analyzed in the 2015 MITT Final EIS/OEIS and the number proposed in this SEIS/OEIS.

Table 3.0-22: Annual Number of Decelerators/Parachutes Expended in the Study Area

Training & Testing		
2015 Final EIS/OEIS	***Alternative 1***	***Alternative 2***
12,572	10 Large, 18 Medium, 5,437 Small	10 Large, 18 Medium, 5,934 Small

3.0.4.6 Ingestion Stressors

As described in the 2015 MITT Final EIS/OEIS, ingestion stressors can result from the Navy's proposed use of non-explosive practice munitions (small- and medium-caliber), fragments from explosives, fragments from targets, chaff, flare casings (including plastic end caps and pistons), and decelerator/parachutes. The annual number of non-explosive practice munitions expended is shown in Table 3.0-14, the number of explosive munitions that could fragment is shown in Table 3.0-16, the number of targets that could fragment is shown in Table 3.0-17, the number of decelerator/parachutes is shown in Table 3.0-22, the number of chaff cartridges is shown in Table 3.0-23, and the number of flares is shown in Table 3.0-24.

Table 3.0-23: Annual Number of Chaff Cartridges Expended in the Study Area

Training & Testing		
2015 Final EIS/OEIS	***Alternative 1***	***Alternative 2***
Chaff – Air Cartridge		
26,000	17,600	17,600
Chaff – Ship Cartridge		
440	246	360

Table 3.0-24: Annual Number of Flares Expended in the Study Area

Training & Testing		
2015 Final EIS/OEIS	***Alternative 1***	***Alternative 2***
25,900	17,600	17,600

3.0.4.7 Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities

This conceptual framework describes the potential effects from exposure to acoustic and explosive activities and the accompanying short-term costs to the animal (e.g., expended energy or missed feeding opportunity). It then outlines the conditions that may lead to long-term consequences for the individual if the animal cannot fully recover from the short-term costs and how these in turn may affect the population. Within each biological resource section (e.g., marine mammals, birds, and fishes) the detailed methods to predict effects on specific taxa are derived from this conceptual framework.

An animal is considered "exposed" to a sound if the received sound level at the animal's location is above the background ambient noise level within a similar frequency band. A variety of effects may result from exposure to acoustic and explosive activities.

The categories of potential effects are:

- ***Injury*** *- Injury to organs or tissues of an animal.*
- ***Hearing loss*** *- A noise-induced decrease in hearing sensitivity that can be either temporary or permanent and may be limited to a narrow frequency range of hearing.*
- ***Masking*** *- When the perception of a biologically important sound (i.e., signal) is interfered with by a second sound (i.e., noise).*
- ***Physiological stress*** *- An adaptive process that helps an animal cope with changing conditions; although, too much stress can result in physiological problems.*
- ***Behavioral response*** *- A reaction ranging from very minor and brief changes in attentional focus, changes in biologically important behaviors, and avoidance of a sound source or area, to aggression or prolonged flight.*

Figure 3.0-3 is a flowchart that diagrams the process used to evaluate the potential effects to marine animals exposed to sound-producing activities. The shape and color of each box on the flowchart represents either a decision point in the analysis (green diamonds); specific processes such as responses, costs, or recovery (blue rectangles); external factors to consider (purple parallelograms); and final outcomes for the individual or population (orange ovals and rectangles). Each box is labeled for reference throughout the following sections. For simplicity, sound is used here to include not only sound waves but also blast waves generated from explosive sources. Box A1, the Sound-Producing Activity, is the source of this stimuli and therefore the starting point in the analysis.

The first step in predicting whether an activity is capable of affecting a marine animal is to define the stimuli experienced by the animal. The stimuli include the overall level of activity, the surrounding acoustical environment, and characteristics of the sound when it reaches the animal.

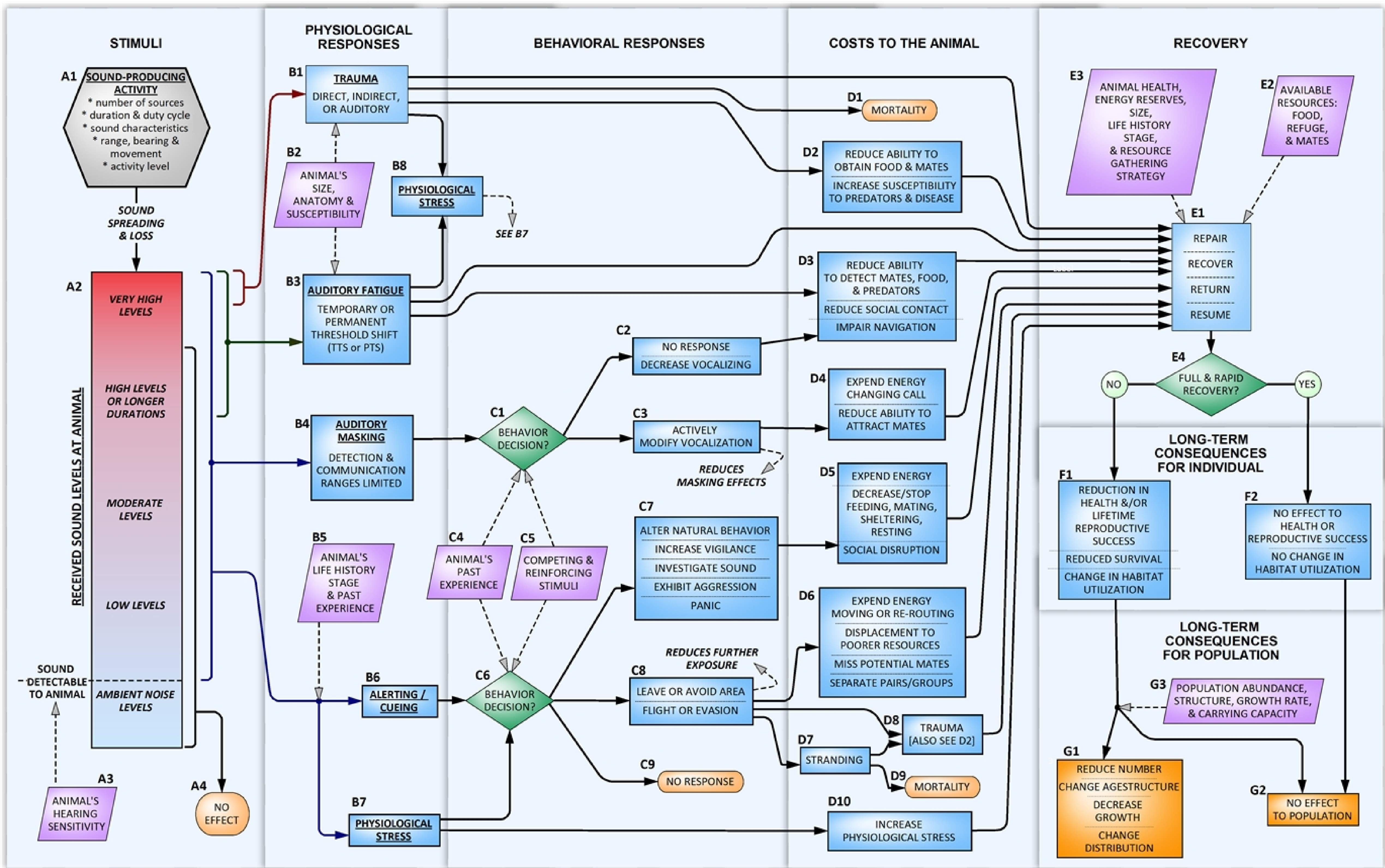

Figure 3.0-3: Flow Chart of the Evaluation Process of Sound-Producing Activities

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Sounds emitted from a sound-producing activity (Box A1) travel through the environment to create a spatially variable sound field. The received sound by the animal (Box A2) determines the range of possible effects. The received sound can be evaluated in several ways, including number of times the sound is experienced (repetitive exposures), total received energy, or highest SPL experienced. Sounds that are higher than the ambient noise level and within an animal's hearing sensitivity range (Box A3) have the potential to cause effects. There can be any number of individual sound sources in a given activity, each with its own unique characteristics. For example, a Navy training exercise may involve several ships and aircraft using several types of sonar. Environmental factors such as temperature and bottom type impact how sound spreads and attenuates through the environment. Additionally, independent of the sounds, the overall level of activity and the number and movement of sound sources are important to help predict the probable reactions.

The magnitude of the responses is based on the characteristics of the acoustic stimuli and the characteristics of the animal (species, susceptibility, life history stage, size, and past experiences). Very high exposure levels close to explosives have the potential to cause injury. High-level, long-duration, or repetitive exposures may potentially cause some hearing loss. All perceived sounds may lead to behavioral responses, physiological stress, and masking. Many sounds, including sounds that are not detectable by the animal, could have no effect (Box A4).

3.0.4.7.1 Injury

Injury (Box B1) refers to the direct injury of tissues and organs by shock or pressure waves impinging upon or traveling through an animal's body. Marine animals are well adapted to large, but relatively slow, hydrostatic pressure changes that occur with changing depth. However, injury may result from exposure to rapid pressure changes, such that the tissues do not have time to adequately adjust.

Therefore, injury is normally limited to relatively close ranges from explosions. Injury can be mild and fully recoverable or, in some cases, lead to mortality.

Injury includes both auditory and non-auditory injury. Auditory injury is the direct mechanical injury to hearing-related structures, including tympanic membrane rupture, disarticulation of the middle ear ossicles, and injury to the inner ear structures such as the organ of Corti and the associated hair cells. Auditory injury differs from auditory fatigue in that the latter involves the overstimulation of the auditory system at levels below those capable of causing direct mechanical damage. Auditory injury is always injurious but can be temporary. One of the most common consequences of auditory injury is hearing loss.

Non-auditory injury can include hemorrhaging of small blood vessels and the rupture of gas-containing tissues such as the lung, swim bladder, or gastrointestinal tract. After the ear (or other sound-sensing organs), these are usually the organs and tissues most sensitive to explosive injury. An animal's size and anatomy are important in determining its susceptibility to non-auditory injury (Box B2). Larger size indicates more tissue to protect vital organs. Therefore, larger animals should be less susceptible to injury than smaller animals. In some cases, acoustic resonance of a structure may enhance the vibrations resulting from noise exposure and result in an increased susceptibility to injury. The size, geometry, and material composition of a structure determine the frequency at which the object will resonate. Because most biological tissues are heavily damped, the increase in susceptibility from resonance is limited.

Vascular and tissue bubble formation resulting from sound exposure is a hypothesized mechanism of injury to breath-holding marine animals. Bubble formation and growth due to direct sound exposure have been hypothesized (Crum & Mao, 1996; Crum et al., 2005); however, the experimental laboratory conditions under which these phenomena were observed would not be replicated in the wild. Certain dive behaviors by breath-holding animals are predicted to result in conditions of blood nitrogen super-saturation, potentially putting an animal at risk for decompression sickness (Fahlman et al., 2014), although this phenomena has not been observed (Houser et al., 2009). In addition, animals that spend long periods of time at great depths are predicted to have super-saturated tissues that may slowly release nitrogen if the animal then spends a long time at the surface (i.e., stranding) (Houser et al., 2009).

Injury could increase the animal’s physiological stress (Box B8), which feeds into the stress response (Box B7) and also increases the likelihood or severity of a behavioral response. Injury may reduce an animal’s ability to secure food by reducing its mobility or the efficiency of its sensory systems, making the injured individual less attractive to potential mates, increasing an individual’s chances of contracting diseases, falling prey to a predator (Box D2), or increasing an animal's overall physiological stress level (Box D10). Severe injury can lead to the death of the individual (Box D1).

Damaged tissues from mild to moderate injury may heal over time. The predicted recovery of direct injury is based on the severity of the injury, availability of resources, and characteristics of the animal. The animal may also need to recover from any potential costs due to a decrease in resource gathering efficiency and any secondary effects from predators or disease. Severe injuries can lead to reduced survivorship (longevity), elevated stress levels, and prolonged alterations in behavior that can reduce an animal’s lifetime reproductive success. An animal with decreased energy stores or a lingering injury may be less successful at mating for one or more breeding seasons, thereby decreasing the number of offspring produced over its lifetime.

3.0.4.7.2 Hearing Loss

Hearing loss, also called a noise-induced threshold shift, is possibly the most studied type of effect from sound exposures to animals. Hearing loss manifests itself as loss in hearing sensitivity across part of an animal’s hearing range, which is dependent upon the specifics of the noise exposure. Hearing loss may be either PTS or TTS. If the threshold shift eventually returns to zero (the animal’s hearing returns to pre-exposure value), the threshold shift is a TTS. If the threshold shift does not return to zero but leaves some finite amount of threshold shift, then that remaining threshold shift is a PTS. Figure 3.0-4 shows one hypothetical threshold shift that completely recovers, a TTS, and one that does not completely recover, leaving some PTS.

The characteristics of the received sound stimuli are used and compared to the animal’s hearing sensitivity and susceptibility to noise (Box A3) to determine the potential for hearing loss. The amplitude, frequency, duration, and temporal pattern of the sound exposure are important parameters for predicting the potential for hearing loss over a specific portion of an animal’s hearing range. Duration is particularly important because hearing loss increases with prolonged exposure time. Longer exposures with lower sound levels can cause more threshold shift than a shorter exposure using the same amount of energy overall. The frequency of the sound also plays an important role. Experiments show that animals are most susceptible to hearing loss (Box B3) within their most sensitive hearing range. Sounds outside of an animal’s audible frequency range do not cause hearing loss.

The mechanisms responsible for hearing loss may consist of a variety of mechanical and biochemical processes in the inner ear, including physical damage or distortion of the tympanic membrane (not including tympanic membrane rupture which is considered auditory injury), physical damage or distortion of the cochlear hair cells, hair cell death, changes in cochlear blood flow, and swelling of cochlear nerve terminals (Henderson et al., 2006; Kujawa & Liberman, 2009). Although the outer hair cells are the most prominent target for fatigue effects, severe noise exposures may also result in inner hair cell death and loss of auditory nerve fibers (Henderson et al., 2006).

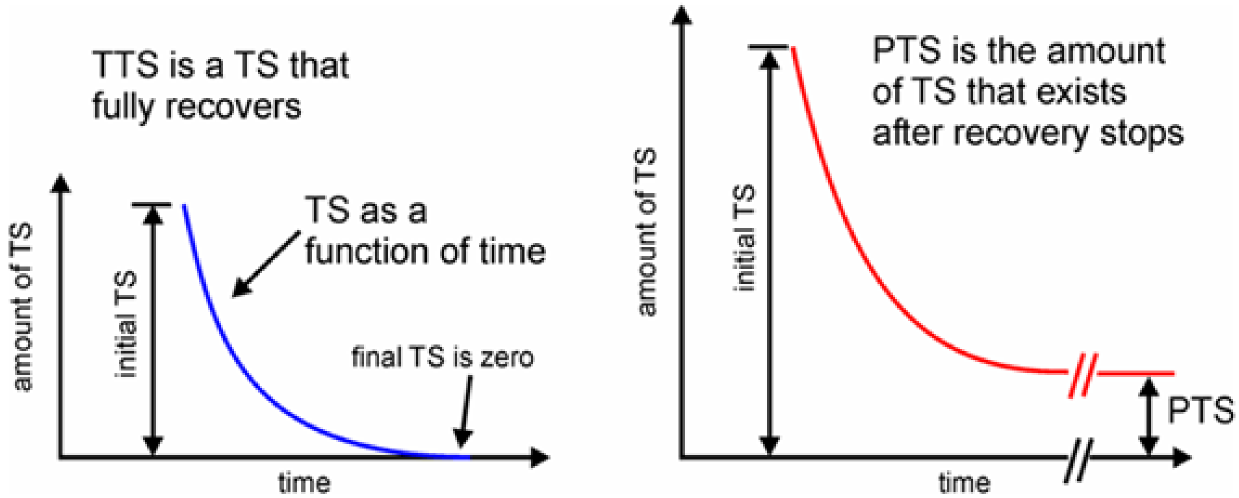

Figure 3.0-4: Two Hypothetical Threshold Shifts

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 decibels measured two minutes after exposure) will recover with no apparent permanent effects; however, terrestrial mammal studies revealed that larger amounts of threshold shift can result in permanent neural degeneration, despite the hearing thresholds returning to normal (Kujawa & Liberman, 2009). The amounts of threshold shift induced by Kujawa and Liberman (2009) were described as being "at the limits of reversibility." It is unknown whether smaller amounts of threshold shift can result in similar neural degeneration, or if effects would translate to other species such as marine animals.

Hearing loss can increase an animal's physiological stress (Box B8), which feeds into the stress response (Box B7). Hearing loss increases the likelihood or severity of a behavioral response and increase an animal's overall physiological stress level (Box D10). Hearing loss reduces the distance over which animals can communicate and detect other biologically important sounds (Box D3). Hearing loss could also be inconsequential for an animal if the frequency range affected is not critical for that animal to hear within, or the hearing loss is of such short duration (e.g., a few minutes) that there are no costs to the individual.

Small to moderate amounts of hearing loss may recover over a period of minutes to days, depending on the amount of initial threshold shift. Severe noise-induced hearing loss may not fully recover, resulting in some amount of PTS. An animal whose hearing does not recover quickly and fully could suffer a reduction in lifetime reproductive success. An animal with PTS may be less successful at mating for one or more breeding seasons, thereby decreasing the number of offspring it can produce over its lifetime.

3.0.4.7.3 Masking

Masking occurs if the noise from an activity interferes with an animal's ability to detect, understand, or recognize biologically relevant sounds of interest (Box B4). In this context noise refers to unwanted or unimportant sounds that mask an animal's ability to hear sounds of interest. Sounds of interest include those from conspecifics such as offspring, mates, and competitors; echolocation clicks; sounds from predators; natural, abiotic sounds that may aid in navigation; and reverberation, which can give an animal information about its location and orientation within the ocean. The probability of masking increases as the noise and sound of interest increase in similarity and the masking noise increases in level. The frequency, received level, and duty cycle of the noise determines the potential degree of auditory masking. Masking only occurs during the sound exposure.

A behavior decision (either conscious or instinctive) is made by the animal when the animal detects increased background noise, or possibly, when the animal recognizes that biologically relevant sounds are being masked (Box C1). An animal's past experiences can be important in determining the behavioral response when dealing with masking (Box C4). For example, an animal may modify its vocalizations to reduce the effects of masking noise. Other stimuli present in the environment can influence an animal's behavior decision (Box C5) such as the presence of predators, prey, or potential mates.

An animal may exhibit a passive behavioral response when coping with masking (Box C2). It may simply not respond and keep conducting its current natural behavior. An animal may also stop calling until the background noise decreases. These passive responses do not present a direct energetic cost to the animal; however, masking will continue, depending on the acoustic stimuli.

An animal may actively compensate for masking (Box C3). An animal can vocalize more loudly to make its signal heard over the masking noise. An animal may also shift the frequency of its vocalizations away from the frequency of the masking noise. This shift can actually reduce the masking effect for the animal and other animals that are listening in the area.

If masking impairs an animal's ability to hear biologically important sounds (Box D3) it could reduce an animal's ability to communicate with conspecifics or reduce opportunities to detect or attract more distant mates, gain information about their physical environment, or navigate. An animal that modifies its vocalization in response to masking could also incur a cost (Box D4). Modifying vocalizations may cost the animal energy, interfere with the behavioral function of a call, or reduce a signaler's apparent quality as a mating partner. For example, songbirds that shift their calls up an octave to compensate for increased background noise attract fewer or less-desirable mates, and many terrestrial species advertise body size and quality with low-frequency vocalizations (Slabbekoorn & Ripmeester, 2007). Masking may also lead to no measurable costs for an animal. Masking could be of short duration or intermittent such that biologically important sounds that are continuous or repeated are received by the animal between masking noise.

Masking only occurs when the sound source is operating; therefore, direct masking effects stop immediately upon cessation of the sound-producing activity. Masking could have long-term consequences for individuals if the activity was continuous or occurred frequently enough.

3.0.4.7.4 Physiological Stress

Marine animals naturally experience physiological stress as part of their normal life histories. The physiological response to a stressor, often termed the stress response, is an adaptive process that helps an animal cope with changing external and internal environmental conditions. Sound-producing activities have the potential to cause additional stress. However, too much of a stress response can be harmful to an animal, resulting in physiological dysfunction.

If a sound is detected (i.e., heard or sensed) by an animal, a stress response can occur (Box B7). The severity of the stress response depends on the received sound level by the animal (Box A2), the details of the sound-producing activity (Box A1), and the animal's life history stage (e.g., juvenile or adult, breeding or feeding season), and past experience with the stimuli (Box B5). An animal's life history stage is an important factor to consider when predicting whether a stress response is likely (Box B5). An animal's life history stage includes its level of physical maturity (i.e., larva, infant, juvenile, sexually mature adult) and the primary activity in which it is engaged such as mating, feeding, or rearing/caring for young. Prior experience with a stressor may be of particular importance because repeated experience with a stressor may dull the stress response via acclimation (St. Aubin & Dierauf, 2001) or increase the response via sensitization. Additionally, if an animal suffers injury or hearing loss, a physiological stress response will occur (Box B8).

The generalized stress response is characterized by a release of hormones (Reeder & Kramer, 2005) and other chemicals (e.g., stress markers) such as reactive oxidative compounds associated with noise-induced hearing loss (Henderson et al., 2006). Stress hormones include norepinephrine and epinephrine (i.e., the catecholamines), which produce elevations in the heart and respiration rate, increase awareness, and increase the availability of glucose and lipid for energy. Other stress hormones are the glucocorticoid steroid hormones cortisol and aldosterone, which are classically used as an indicator of a stress response and to characterize the magnitude of the stress response (Hennessy et al., 1979).

An acute stress response is traditionally considered part of the startle response and is hormonally characterized by the release of the catecholamines. Annoyance type reactions may be characterized by the release of either or both catecholamines and glucocorticoid hormones. Regardless of the physiological changes that make up the stress response, the stress response may contribute to an animal's decision to alter its behavior.

Elevated stress levels may occur whether or not an animal exhibits a behavioral response (Box D10). Even while undergoing a stress response, competing stimuli (e.g., food or mating opportunities) may overcome any behavioral response. Regardless of whether the animal displays a behavioral response, this tolerated stress could incur a cost to the animal. Reactive oxygen compounds produced during normal physiological processes are generally counterbalanced by enzymes and antioxidants; however, excess stress can lead to damage of lipids, proteins, and nucleic acids at the cellular level (Berlett & Stadtman, 1997; Sies, 1997; Touyz, 2004).

Frequent physiological stress responses may accumulate over time increasing an animal's chronic stress level. Each component of the stress response is variable in time, and stress hormones return to baseline levels at different rates. Elevated chronic stress levels are usually a result of a prolonged or repeated disturbance. Chronic elevations in the stress levels (e.g., cortisol levels) may produce long-term health consequences that can reduce lifetime reproductive success.

3.0.4.7.5 Behavioral Reactions

Behavioral responses fall into two major categories: alterations in natural behavior patterns and avoidance. These types of reactions are not mutually exclusive, and many overall reactions may be combinations of behaviors or a sequence of behaviors. Severity of behavioral reactions can vary drastically between minor and brief reorientations of the animal to investigate the sound, to severe reactions such as aggression or prolonged flight. The type and severity of the behavioral response will determine the cost to the animal. The total number of vessels and platforms involved, the size of the activity area, the distance between the animal and activity, and the duration of the activity are important considerations when predicting the initial behavioral responses.

A physiological stress response (Box B7) such as an annoyance or startle reaction, or cueing or alerting (Box B6) may cause an animal to make a behavior decision (Box C6). Any exposure that produces an injury or hearing loss is also assumed to produce a stress response (Box B7) and increase the severity or likelihood of a behavioral reaction. Both an animal's experience (Box C4) and competing and reinforcing stimuli (Box C5) can affect an animal's behavior decision. The decision can result in three general types of behavioral reactions: no response (Box C9), area avoidance (Box C8), or alteration of a natural behavior (Box C7).

An animal’s past experiences can be important in determining what behavior decision it may make when dealing with a stress response (Box C4). Habituation is the process by which an animal learns to ignore or tolerate stimuli over some period and return to a normal behavior pattern, perhaps after being exposed to the stimuli with no negative consequences. Sensitization is when an animal becomes more sensitive to a set of stimuli over time, perhaps as a result of a past, negative experience that could result in a stronger behavioral response.

Other stimuli (Box C5) present in the environment can influence an animal’s behavioral response. These stimuli may be conspecifics or predators in the area or the drive to engage in a natural behavior. Other stimuli can also reinforce the behavioral response caused by acoustic stimuli. For example, the awareness of a predator in the area coupled with the sound-producing activity may elicit a stronger reaction than the activity alone would have.

An animal may reorient, become more vigilant, or investigate if it detects a sound-producing activity (Box C7). These behaviors all require the animal to divert attention and resources, therefore slowing or stopping their presumably beneficial natural behavior. This can be a very brief diversion, or an animal may not resume its natural behaviors until after the activity has concluded. An animal may choose to leave or avoid an area where a sound-producing activity is taking place (Box C8). A more severe form of this comes in the form of flight or evasion. Avoidance of an area can help the animal avoid further effects by avoiding or reducing further exposure. An animal may also choose not to respond to a sound-producing activity (Box C9).

An animal that alters its natural behavior in response to stress or an auditory cue may slow or cease its natural behavior and instead expend energy reacting to the sound-producing activity (Box D5). Natural behaviors include feeding, breeding, sheltering, and migrating. The cost of feeding disruptions depends on the energetic requirements of individuals and the potential amount of food missed during the disruption. Alteration in breeding behavior can result in delaying reproduction. The costs of a brief interruption to migrating or sheltering are less clear.

An animal that avoids a sound-producing activity may expend additional energy moving around the area, be displaced to poorer resources, miss potential mates, or have social interactions affected (Box D6). The amount of energy expended depends on the severity of the behavioral response. Missing potential mates can result in delaying reproduction. Groups could be separated during a severe behavioral response such as flight and offspring that depend on their parents may die if they are permanently separated. Splitting up an animal group can result in a reduced group size, which can have secondary effects on individual foraging success and susceptibility to predators.

Some severe behavioral reactions can lead to stranding (Box D7) or secondary injury (Box D8). Animals that take prolonged flight, a severe avoidance reaction, may injure themselves or strand in an environment for which they are not adapted. Some injury is likely to occur to an animal that strands (Box D8). Injury can reduce the animal's ability to secure food and mates, and increase the animal's susceptibility to predation and disease (Box D2). An animal that strands and does not return to a hospitable environment may die (Box D9).

3.0.4.7.6 Long-Term Consequences

The potential long-term consequences from behavioral responses are difficult to discern. Animals displaced from their normal habitat due to an avoidance reaction may return over time and resume their natural behaviors. This is likely to depend upon the severity of the reaction and how often the activity is repeated in the area. In areas of repeated and frequent acoustic disturbance, some animals may habituate to the new baseline; conversely, species that are more sensitive may not return, or return but not resume use of the habitat in the same manner. For example, an animal may return to an area to feed but no longer rest in that area. Long-term abandonment or a change in the utilization of an area by enough individuals can change the distribution of the population. Frequent disruptions to natural behavior patterns may not allow an animal to recover between exposures, which increase the probability of causing long-term consequences to individuals.

The magnitude and type of effect and the speed and completeness of recovery (i.e., return to baseline conditions) must be considered in predicting long-term consequences to the individual animal (Box E4). The predicted recovery of the animal (Box E1) is based on the cost to the animal from any reactions, behavioral or physiological. Available resources fluctuate by season, location, and year and can play a major role in an animal's rate of recovery (Box E2). Recovery can occur more quickly if plentiful food resources, many potential mates, or refuge or shelter is available. An animal's health, energy reserves, size, life history stage, and resource gathering strategy affect its speed and completeness of recovery (Box E3). Animals that are in good health and have abundant energy reserves before an effect takes place will likely recover more quickly.

Animals that recover quickly and completely are unlikely to suffer reductions in their health or reproductive success, or experience changes in habitat utilization (Box F2). No population-level effects would be expected if individual animals do not suffer reductions in their lifetime reproductive success or change their habitat utilization (Box G2). Animals that do not recover quickly and fully could suffer reductions in their health and lifetime reproductive success; they could be permanently displaced or change how they use the environment; or they could die (Box F1). These long-term consequences to the individual can lead to consequences for the population (Box G1); although, population dynamics and abundance play a role in determining how many individuals would need to suffer long-term consequences before there was an effect on the population.

Long-term consequences to individuals can translate into consequences for populations dependent upon population abundance, structure, growth rate, and carry capacity. Carrying capacity describes the theoretical maximum number of animals of a particular species that the environment can support. When a population nears its carrying capacity, its growth is naturally limited by available resources and predator pressure. If one, or a few animals, in a population are removed or gather fewer resources, then other animals in the population can take advantage of the freed resources and potentially increase their health and lifetime reproductive success. Abundant populations that are near their carrying capacity (theoretical maximum abundance) that suffer consequences on a few individuals may not be affected overall. Populations that exist well below their carrying capacity may suffer greater consequences from any lasting consequences to even a few individuals. Population-level consequences can include a change in the population dynamics, a decrease in the growth rate, or a change in geographic distribution.

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