# 3 Affected Environment and Environmental Consequences

# Gulf of Alaska Navy Training Activities

# Draft Supplemental Environmental Impact Statement/

# Overseas Environmental Impact Statement

## TABLE OF CONTENTS

## List of Tables

# List of Figures

# 3 AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

## 3.0 Introduction

This chapter outlines the United States (U.S.) Department of the Navy's (Navy's) rationale for resource analysis in the Gulf of Alaska (GOA) Navy Training Activities Supplemental Environmental Impact Statement (SEIS)/Overseas Environmental Impact Statement (OEIS).

In accordance with 40 Code of Federal Regulations (CFR) section 1502.9(c) (2019), Agencies:

> (1) Shall prepare supplements to either draft or final environmental impact statements if:
>
> > (i) The agency makes substantial changes in the proposed action that are relevant to environmental concerns; or
> >
> > (ii) There are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts.
>
> (2) May also prepare supplements when the agency determines that the purposes of the Act will be furthered by doing so.
>
> (3) Shall adopt procedures for introducing a supplement into its formal administrative record, if such a record exists.
>
> (4) Shall prepare, circulate, and file a supplement to a statement in the same fashion (exclusive of scoping) as a draft and final statement unless alternative procedures are approved by the Council [on Environmental Quality].

In March 2011, the Navy released the GOA Navy Training Activities Final Environmental Impact Statement (EIS)/OEIS (U.S. Department of the Navy, 2011a), hereafter referred to as the 2011 GOA Final EIS/OEIS, for which a Record of Decision (ROD) was received (*Record of Decision for Final Environmental Impact Statement/Overseas Environmental Impact Statement for the Gulf of Alaska Navy Training Activities* (U.S. Department of the Navy, 2011b) pursuant to the guidance of 40 CFR section 1502.9(c). In July 2016, the Navy released the GOA Navy Training Activities Final SEIS/OEIS (U.S. Department of the Navy, 2016), hereafter referred to as the 2016 GOA Final SEIS/OEIS, for which a ROD was received (*Record of Decision for Final Environmental Impact Statement/Overseas Environmental Impact Statement for the Gulf of Alaska Navy Training Activities* (U.S. Department of the Navy, 2017c)) pursuant to the guidance of 40 CFR Section 1502.9(c). For the 2016 GOA Final SEIS/OEIS, the Navy, in coordination with the National Marine Fisheries Service (NMFS), applied the Navy Acoustic Effects Model to quantitatively analyze potential acoustic effects from Navy training activities. For this SEIS/OEIS, the Navy refined the Navy Acoustic Effects Model (U.S. Department of the Navy, 2018) and updated marine mammal density estimates (U.S. Department of the Navy, 2020), as well as the criteria and activity data inputs used in the acoustic model (U.S. Department of the Navy, 2017a).

This chapter describes existing environmental conditions in the Study Area (the Temporary Maritime Activities Area [TMAA]) as well as the analysis of resources potentially impacted by the Proposed Action described in Chapter 2 (Description of Proposed Action and Alternatives). The TMAA is described in Section 2.2 (Gulf of Alaska Temporary Maritime Activities Area) and depicted in Figure 2-1.

### 3.0.1 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 2011 GOA Final EIS/OEIS and ROD.
- Review the existing 2016 GOA Final SEIS/OEIS and ROD.
- Review existing federal and state regulations and standards relevant to resource-specific management or protection.
- Review and apply new literature, to include new surveys; new information on habitat; new information on how resources could be affected by stressors; as well as new literature, laws, regulations, and publications pertaining to the resources identified in the 2011 GOA Final EIS/OEIS and the 2016 GOA Final SEIS/OEIS.
- Describe any changes to existing resource conditions from the 2011 GOA Final EIS/OEIS and ROD and the 2016 GOA Final SEIS/OEIS and ROD.
    - Determine if an existing activity needs to be re-analyzed based upon a change in the activity.
    - Determine if the affected environment has changed.
    - Determine if there is a new method of analysis for the existing activity.
- Identify resource sections for re-analysis within this SEIS/OEIS.
    - Analyze resource-specific impacts for individual stressors.[1]
    - Examine potential population-level impacts.
- Analyze 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 Executive Order 12114.

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

##### 3.0.1.1.1 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 2005, both in association with training and testing events and independently. This also includes marine species monitoring in the Gulf of Alaska from 2011 to 2020. 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

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[1] The term "stressor" is broadly used in this document to refer to an agent, condition, or other stimulus that causes stress to an organism or alters physical, socioeconomic, or cultural resources.

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. The most recent of federally funded marine mammal research and conservation conducted by the Marine Mammal Commission found that the Navy was the third-largest source of funding for marine mammal activities at $20.07M (direct project expenditures, as well as associated indirect or support costs) in the United States in 2019, behind only to National Oceanic and Atmospheric Administration Fisheries ($36.60M) and National Science Foundation ($20.23M) (U.S. Marine Mammal Commission, 2020).

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 and ESA-listed fish 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's Marine Species Monitoring Program website (https://www.navymarinespeciesmonitoring.us/), which serves as a public online portal for information on the background, history, and progress of the program and also provides access to reports, documentation, data, and updates on current monitoring projects and initiatives.

The two other Navy programs previously mentioned invest in research on the potential effects of sound on marine species and develop scientific information and analytic tools that support preparation of environmental impact statements and associated regulatory processes under the MMPA and ESA, as well as support development of improved monitoring and detection technology and advance overall knowledge about marine species. These programs support coordinated science, technology, research, and development focused on understanding the effects of sound on marine mammals and other marine species, including physiological, behavioral, ecological, and population-level effects. Additional information on these programs and other ocean resources-oriented initiatives can be found on the Living Marine Resources Program page at https://www.navfac.navy.mil/navfac_worldwide/specialty_centers/exwc/products_and_services/ev/lmr.html.

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

The 2011 GOA Final EIS/OEIS used an acoustic modeling methodology, marine mammal density information, and scientific information that was the best available at the time. Following the completion of the 2011 GOA Final EIS/OEIS, the 2016 GOA Final SEIS/OEIS evaluated acoustic impacts using a modeling system known as Navy Acoustic Effects Model, which was developed by the Navy in cooperation with NMFS (as a cooperating agency) to conduct a comprehensive acoustic impact analysis for in-water training activities. The analysis in this SEIS/OEIS continues to utilize relevant new scientific information, the latest marine species density data available, and refinements to the analytical methods and modeling processes for estimating potential effects to marine species.

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 Acoustics Effects Model takes the density and the criteria and thresholds as inputs and analyzes Navy training activities.

Finally, mitigation and animal avoidance behaviors are considered to determine the number of impacts that could occur. The inputs and process are described below. A detailed explanation of this analysis is provided in the technical report titled *Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase III Training and Testing* (U.S. Department of the Navy, 2018).

#### 3.0.1.1.3 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 is the primary agency responsible for estimating marine mammal densities 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 TMAA, 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 species present within the TMAA. This database is described in the technical report titled *U.S. Navy Marine Species Density Database Phase III for the Gulf of Alaska Study Area* (U.S. Department of the Navy, 2020), 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 list below 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 (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 TMAA, 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, 2020). 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.

#### 3.0.1.1.4 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 (i.e., leatherback sea turtles). Criteria for estimating impacts on marine fishes are also used in this analysis, which largely follows the *ANSI 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 (i.e., leatherback 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, 2017a), 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 3.6 (Fish). 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).

#### 3.0.1.1.5 The Navy Acoustic Effects Model

The Navy Acoustic Effects Model calculates sound energy propagation from sonar and other transducers and explosives during naval activities and the energy or sound received by animat dosimeters. Animat dosimeters are virtual representations of marine mammals and sea turtles (i.e., leatherback 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 TMAA 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 animats. 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 (i.e., leatherback 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 and 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 (i.e., leatherback sea turtles) would avoid continued or repeated sound exposures is also considered.
- Many explosions from munitions such as bombs and medium-caliber and large-caliber projectiles actually occur upon impact with targets located on or near the surface of the water. However, for this analysis, sources such as these were modeled as exploding in water. This modeling overestimates the amount of explosive and acoustic energy entering the water.

The model estimates the impacts caused by individual training 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 (i.e., leatherback 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 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 Acoustic Effects Model is provided in the technical report *Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase III Training and Testing* (U.S. Department of the Navy, 2018).

The Navy Acoustic Effects Model also estimates range to effects by modeling the distance that noise from a sonar or other transducer, or an explosion will need to propagate to reach hearing group-specific exposure thresholds for behavioral response, temporary threshold shift (TTS), permanent threshold shift (PTS), non-auditory injury, and mortality. **Error! Reference source not found.**Figure 3.0-1 provides a hypothetical example of range to effects along one radial from a sonar source for PTS (green), TTS (cyan), behavioral (purple), and no effects (blue) while considering the maximum dive depth of 300 m for species A (white dashed line). Range to effects are bound by a species' maximum dive depth, and only the data less than or equal to a species maximum dive depth are used to estimate impact ranges. For example, only the data less than or equal to 300 m depth are considered for impact ranges for species A, and the point the maximum dive depth line intersects with the edge of a colored impact region depicts the range to those effects (PTS 688 m [green star], TTS, 1,406 m [cyan star], behavioral 1,594 m [purple star]). Since these ranges do not represent a cylinder of effect in the water column, there are portions of the water column within these ranges that would not exceed threshold. For example, from 0 to 300 m in depth, and from 0 to 688 m in range, exposure thresholds for PTS would not be exceeded in regions that are cyan, purple or blue. In some instances, a significant portion of the water column within an impact range may not exceed threshold. These differences in propagation are captured in the actual estimation of takes within the Navy Acoustic Effects Model.

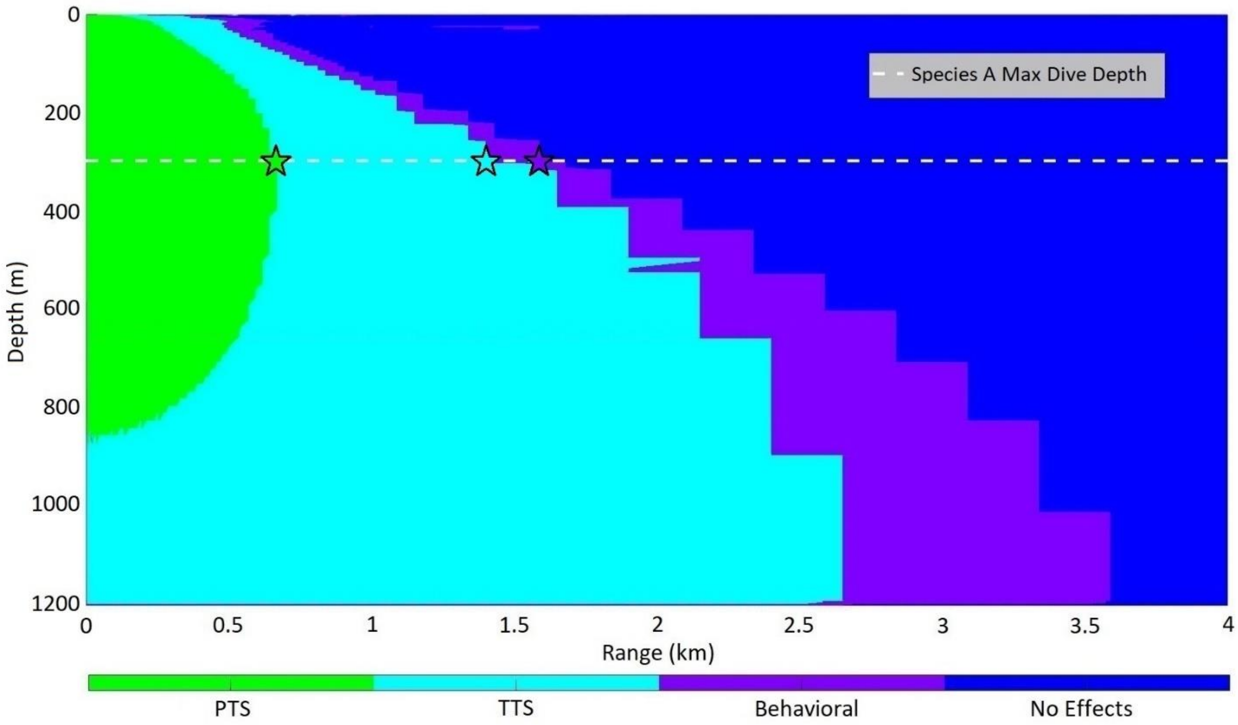

**Figure 3.0-1: Hypothetical Range to Effects Example**

#### 3.0.1.1.6 Accounting for Mitigation

##### 3.0.1.1.6.1 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 (i.e., leatherback 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 PTS) for a given sonar exposure. Therefore, the impact analysis quantifies the potential for mitigation to reduce the risk of PTS. Two factors are considered when quantifying the effectiveness of mitigation: (1) the extent to which the type of mitigation proposed for a sound-producing activity (e.g., active sonar) allows for observation of the mitigation zone prior to and during the activity; and (2) the sightability of each species that may be present in the mitigation zone, which is determined by species-specific characteristics and the viewing platform. A detailed explanation of the analysis is provided in the technical report *Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase III Training and Testing* (U.S. Department of the Navy, 2018).

In the quantitative analysis, consideration of mitigation measures means that, for activities where mitigation is feasible, some model-estimated PTS is considered mitigated to the level of 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 event. The ability of Navy Lookouts to detect marine mammals or sea turtles (i.e., leatherback 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 activity could take place are also considered, such as the sea surface conditions, weather (e.g., fog or rain), and day versus night.

###### 3.0.1.1.6.2 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 (i.e., leatherback sea turtle) is observed in the mitigation zone. The mitigation zones encompass the estimated ranges to mortality for a given explosive. Navy impact analyses typically consider the potential for procedural mitigation to reduce the risk of mortality due to exposure to explosives; however, the Navy Acoustic Effects Model estimated zero mortality takes for all marine mammal species and sea turtles (i.e., leatherback sea turtles) in the TMAA. Therefore, mitigation for explosives is discussed qualitatively but was not factored into the quantitative analysis for marine mammals or sea turtles under Alternative 1. A detailed explanation of the quantitative analysis process is provided in the technical report *Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase III Training and Testing* (U.S. Department of the Navy, 2018).

##### 3.0.1.1.7 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 for implementing the requirements of NEPA, other planning and environmental review procedures are integrated in this SEIS/OEIS to the fullest extent possible. Some of the federal statutes and executive orders described in the 2016 GOA Final SEIS/OEIS (Section 3.0.2.1, Applicable Federal Statutes) have changed since the publishing of the 2016 GOA Final SEIS/OEIS. New, changed, or revoked federal statutes or executive orders are found in Chapter 6 (Additional Regulatory Considerations).

Chapter 6 (Additional Regulatory Considerations) provides a summary listing and status of compliance with the applicable environmental laws, regulations, and executive orders that were considered in preparing this SEIS/OEIS (including those that may be secondary considerations in the resource evaluations).

### 3.0.3 Resources and Issues Considered for Re-Evaluation in This Document

The same resources that were identified and analyzed in the 2011 GOA Final EIS/OEIS and the 2016 GOA Final SEIS/OEIS were considered for reanalysis for this SEIS/OEIS and for reanalysis of cumulative impacts. Those physical resources include air quality, expended materials, water resources, and acoustic environment (airborne). Biological resources (including threatened and endangered species) considered include marine plants and invertebrates, fish, sea turtles, marine mammals, and birds. Human resources and issues considered in this SEIS/OEIS include cultural resources, transportation and circulation, socioeconomics, environmental justice and protection of children, and public safety.

For purposes of consistency across all environmental compliance planning conducted under the Navy's At-Sea Policy (see Section 1.2, The Navy's Environmental Compliance and At-Sea Policy), the Navy realigned the resources in this SEIS/OEIS with those of other Navy at-sea projects. The same resources continue to be analyzed, but that analysis in some instances may be shifted into new or renamed resource sections as depicted in Table 3.0-1.

As shown in Table 3.0-1, the following resource sections remain unchanged: Section 3.1 (Air Quality), Section 3.7 (Sea Turtles), Section 3.8 (Marine Mammals), Section 3.9 (Birds), and Section 3.10 (Cultural Resources).

Section 3.2 (Expended Materials) and Section 3.3 (Water Resources) are now analyzed in Section 3.2 (Sediments and Water Quality); Section 3.4 (Acoustic Environment) is analyzed in each of the other resource sections, but is primarily analyzed as a stressor to public health (Section 3.12, Public Health and Safety); Section 3.5 (Marine Plants and Invertebrates) is now analyzed as three distinct resources—Section 3.3 (Marine Habitats), Section 3.4 (Marine Vegetation), and Section 3.5 (Marine Invertebrates); Section 3.6 (Fish) remains Section 3.6 and is changed to "Fishes;" Section 3.11 (Transportation), Section 3.12 (Socioeconomics), and Section 3.13 (Environmental Justice) are now analyzed in Section 3.11 (Socioeconomic Resources and Environmental Justice). Section 3.14 (Public Safety) is now Section 3.12 (Public Health and Safety) and includes the analysis of the acoustic environment.

Similar to the 2016 GOA Final SEIS/OEIS, this SEIS/OEIS is being conducted because there is new information and analytical methods to analyze acoustic and explosive impacts on fishes, sea turtles, marine mammals, and birds. In the process of preparing this SEIS/OEIS, the Navy has also taken into account new research, literature, laws, and regulations that have emerged since the publication of the 2016 GOA Final SEIS/OEIS that may affect other resource areas. Subsequently, the Navy used this information to identify and evaluate all the resource areas to determine which ones required reanalysis in this SEIS/OEIS.

## Table 3.0-1: Chapter 3 Resource Section Reorganization

| *2011/2016 Section #* | *2011/2016 Section Title* | *Notes* | *2020 Draft SEIS/OEIS Section #* | *2020 Draft SEIS/OEIS Section Title* |
|---|---|---|---|---|
| 3.1 | Air Quality | No change | 3.1 | Air Quality |
| | | | | |
| 3.2 | Expended Materials | Merged into Sediments and Water Quality | 3.2 | Sediments and Water Quality |
| 3.3 | Water Resources | Merged into Sediments and Water Quality | | |
| | | | | |
| 3.4 | Acoustic Environment | Merged into Public Health and Safety | *See new Section 3.12 Public Health and Safety below* | |
| | | | | |
| 3.5 | Marine Plants and Invertebrates | Split into three sections | 3.3 | Marine Habitats |
| | | | 3.4 | Marine Vegetation |
| | | | 3.5 | Marine Invertebrates |
| | | | | |
| 3.6 | Fish | Changed to Fishes | 3.6 | Fishes |
| 3.7 | Sea Turtles | No change | 3.7 | Sea Turtles |
| 3.8 | Marine Mammals | No change | 3.8 | Marine Mammals |
| 3.9 | Birds | No change | 3.9 | Birds |
| 3.10 | Cultural Resources | No change | 3.10 | Cultural Resources |
| | | | | |
| 3.11 | Transportation | Merged into Socioeconomic Resources and Environmental Justice | 3.11 | Socioeconomic Resources and Environmental Justice |
| 3.12 | Socioeconomics | | | |
| 3.13 | Environmental Justice | | | |
| | | | | |
| 3.14 | Public Safety | Changed to Public Health and Safety | 3.12 | Public Health and Safety |
| 3.4 | Acoustic Environment | Merged into Public Health and Safety | | |

#### 3.0.3.1 Resources Not Carried Forward for Reanalysis

No new Navy training activities are proposed in the TMAA in this SEIS/OEIS and, for several of the resources, the existing baseline conditions have not changed appreciably. There have been changes in some platforms and systems (e.g., EA-6B aircraft and frigate, and their associated systems, have been retired) used as part of the proposed activities, but those changes would not affect the analysis or change the conclusions reached in the 2016 GOA Final SEIS/OEIS. The Navy determined that new research, literature, laws, and regulatory guidance addressed in this SEIS/OEIS resulted in little or no change to the findings of the impact analyses in the 2016 GOA Final SEIS/OEIS. Therefore, the impact assessments from the 2016 GOA Final SEIS/OEIS are incorporated by reference for each of the following resource areas (section numbers and names align with the new organization of sections described above) and they are not described further in this SEIS/OEIS:

- 3.1 Air Quality – The Proposed Action in this SEIS/OEIS is consistent with the Proposed Action from the 2016 GOA Final SEIS/OEIS. No new activities are being proposed in this SEIS/OEIS that would affect air quality in the TMAA.
- 3.2 Sediments and Water Quality – The Proposed Action in this SEIS/OEIS is consistent with the Proposed Action from the 2016 GOA Final SEIS/OEIS. There is new information on existing environmental conditions, including updated Navy regulations, since the analysis in the 2016 GOA Final SEIS/OEIS. However, this new information does not significantly change the affected environment. Based on findings from much more intensively used locations, effects on sediments from the use of explosive munitions during training activities in the Study Area would be negligible by comparison. As a result, explosives and explosives byproducts would have no meaningful effect on sediments or water quality in the Study Area.
- 3.3 Marine Habitats – The Proposed Action in this SEIS/OEIS is consistent with the Proposed Action from the 2016 GOA Final SEIS/OEIS. There is no information on existing environmental conditions that significantly changes the affected environment.
- 3.4 Marine Vegetation – The Proposed Action in this SEIS/OEIS is consistent with the Proposed Action from the 2016 GOA Final SEIS/OEIS and the existing baseline conditions have not changed appreciably.
- 3.5 Marine Invertebrates – The Proposed Action in this SEIS/OEIS is consistent with the Proposed Action from the 2016 GOA Final SEIS/OEIS and the existing baseline conditions have not changed appreciably.
- 3.10 Cultural Resources – The Proposed Action in this SEIS/OEIS is consistent with the Proposed Action from the 2016 GOA Final SEIS/OEIS and the existing baseline conditions have not changed appreciably. After consultations with Alaska Native tribes from the Kodiak and Kenai Peninsula region, the Navy confirmed that training events in the TMAA would not involve the use of any explosives in one particular and well-defined fishing area known as Portlock Bank. There are still no relevant subsistence uses of marine mammals implicated by this action. None of the training activities in the Study Area occur where traditional Arctic subsistence hunting exists.
- 3.12 Public Health and Safety – The Proposed Action in this SEIS/OEIS is consistent with the Proposed Action from the 2016 GOA Final SEIS/OEIS and the existing baseline conditions have not changed appreciably.

#### 3.0.3.2 Resources Carried Forward for Reanalysis

Fishes (Section 3.6) and Sea Turtles (Section 3.7) were carried forward for reanalysis because new, significant research has become available since 2016. Marine Mammals (Section 3.8) was reanalyzed because of changes to regulations, significant changes to existing conditions, and the availability of new, significant research. Birds (Section 3.9) was reanalyzed because of changes to regulations and the availability of new, significant research. Socioeconomic Resources and Environmental Justice (Section 3.11) was reanalyzed because of changes in the existing conditions, primarily commercial fish harvest.

### 3.0.4 Stressors-Based Analysis

As stated in the 2016 GOA Final SEIS/OEIS, Navy activities are assessed in this SEIS/OEIS by evaluating the impacts of the various stressors associated with the activities.

The term stressor is broadly used in this document to refer to an agent, condition, or other stimulus that potentially causes stress to an organism or alters physical, socioeconomic, or cultural resources. The

Navy has updated the list of stressors for all of its at-sea planning documents to provide more consistency between documents and to better reflect that certain types of activities affect the environment in the same way.

Table 3.0-2 shows the stressors analyzed in the 2011 Final GOA EIS/OEIS (left-hand column), the new stressor naming convention used in other Navy at-sea projects (center column), and which of the stressors are carried forward in this SEIS/OEIS (right-hand column). There were no appreciable changes in the science or in the occurrence (i.e., location and frequency) of several of the stressors; therefore, those stressors were not reanalyzed.

### Table 3.0-2: Updated List of Stressors Considered for Analysis

| *2011 GOA Final EIS/OEIS* | *Updated Stressor List* | *2020 GOA Draft SEIS/OEIS* |
|---|---|---|
| Vessel Movements | Vessel Noise | Not reanalyzed |
| | Vessel Strike | Not reanalyzed |
| Aircraft Overflights | Aircraft Noise | Not reanalyzed |
| | Aircraft and Aerial Target Strike (Birds) | Not reanalyzed |
| Explosive Ordnance | In-Air Explosions | Reanalyzed for Birds |
| | In-Water Explosions[1] | Reanalyzed for all biological resources |
| Sonar | Sonar and Other Active Acoustic Sources | Reanalyzed for all biological resources |
| Weapons Firing Disturbance | Weapons Noise | Not reanalyzed |
| Expended Materials | Physical Disturbance and Strike | Not reanalyzed |
| | Entanglement | Not reanalyzed |
| | Ingestion | Not reanalyzed |

[1] All in-water explosions in the TMAA occur at or near the ocean surface.

Other information that was evaluated to identify and analyze stressors included public and agency scoping comments, previous environmental analyses, agency consultations, resource-specific information, and applicable laws, regulations, and executive orders. This stressor-based analysis process was used to focus the information presented and analyzed in the affected environment and environmental consequences sections of this SEIS/OEIS.

As previously mentioned, this SEIS/OEIS analyzed the same warfare areas and activities that produce underwater sound as were analyzed in the 2011 GOA Final EIS/OEIS and the 2016 GOA Final SEIS/OEIS. However, in this SEIS/OEIS, the analysis included refinements to the Navy Acoustic Effects Model, new threshold criteria, and updated marine mammal density data as compared to the 2011 GOA Final EIS/OEIS and the 2016 GOA Final SEIS/OEIS. Appendix A (Navy Activities Descriptions) identifies the acoustic and explosive stressors for the analysis of marine mammals, birds, and fish.

#### 3.0.4.1 Acoustic Sources

This section describes the characteristics of sounds produced during naval training and the relative magnitude and location of these sound-producing activities. This section provides the basis for analysis of acoustic impacts on fish, marine mammals, and birds 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 B (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 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 noise 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 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 and high-frequency hull-mounted sonars used to find and track potential enemy submarines; 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 B (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 TMAA.

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

#### 3.0.4.1.1.1 Anti-Submarine Warfare Sonar

Sonar used during anti-submarine warfare (ASW) 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 ASW 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 ASW events occur over a limited area and are completed in less than one day, often within a few hours. Multi-day ASW events requiring coordination of movement and effort between multiple platforms with active sonar over a larger area occur less often, but constitute a large portion of the overall non-impulsive underwater noise from Navy activities, due to periods of concentrated, near-continuous (i.e., 2–8 hours) ASW sonar use by several platforms throughout the duration of the exercise.

#### 3.0.4.1.1.2 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.

#### 3.0.4.1.1.3 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 TMAA. These sources typically have low duty cycles and are usually only used when it is desirable to send a detectable acoustic message.

#### 3.0.4.1.1.4 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 (m) 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 1 micropascal (dB re 1 µPa), but less than 180 dB re 1 µPa
    - Equal to 180 dB re 1 µPa and up to and including 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 duration, beam pattern, and duty cycle

The bins used for classifying active sonars and transducers that are quantitatively analyzed in the TMAA are shown in Table 3.0-3, including annual bin quantities. While general parameters or source characteristics are shown in the table, actual source parameters are classified.

**Table 3.0-3: Sonar and Transducer Sources Quantitatively Analyzed in the Temporary Maritime Activities Area**

| For Annual Training Activities | | | | | |
|---|---|---|---|---|---|
| **Source Class Category** | **Source Class** | **Description** | **Units** | **2011 & 2016 Alternative 1 (Annual)** | **Alternative 1 (Annual)** |
| **Mid-Frequency (MF)** Tactical and non-tactical sources that produce signals from 1 to 10 kHz | MF1 | Hull-mounted surface ship sonars (e.g., AN/SQS-53C and AN/SQS-60) | H | 271 | 271 |
| | MF3 | Hull-mounted submarine sonars (e.g., AN/BQQ-10) | H | 24 | 25 |
| | MF4 | Helicopter-deployed dipping sonars (e.g., AN/AQS-22) | H | 27 | 27 |
| | MF5 | Active acoustic sonobuoys (e.g., DICASS) | I | 126 | 126 |
| | MF6 | Active underwater sound signal devices (e.g., MK 84) | I | 11 | 14 |
| | MF11 | Hull-mounted surface ship sonars with an active duty cycle greater than 80% | H | 39 | 42 |
| | MF12 | Towed array surface ship sonars with an active duty cycle greater than 80% | H | 0 | 14 |

### Table 3.0-3: Sonar and Transducer Sources Quantitatively Analyzed in the Temporary Maritime Activities Area (continued)

| For Annual Training Activities | | | | | |
|---|---|---|---|---|---|
| **Source Class Category** | **Source Class** | **Description** | **Units** | **2011 & 2016 Alternative 1 (Annual)** | **Alternative 1 (Annual)** |
| **High-Frequency (HF)** Tactical and non-tactical sources that produce signals greater than 10 kHz but less than 100 kHz | HF1 | Hull-mounted submarine sonars (e.g., AN/BQQ-10) | H | 12 | 12 |
| | HF6 | Active sources (equal to 180 dB and up to 200 dB) not otherwise binned | H | 40 | 0 |
| **Anti-Submarine Warfare (ASW)** Tactical sources used during anti-submarine warfare training activities | ASW1 | MF systems operating above 200 dB | H | 0 | 14 |
| | ASW2 | MF Multistatic Active Coherent sonobuoy (e.g., AN/SSQ-125) | H | 40 | 42 |
| | ASW3 | MF towed active acoustic countermeasure systems (e.g., AN/SLQ-25) | H | 273 | 273 |
| | ASW4 | MF expendable active acoustic device countermeasures (e.g., MK3) | I | 6 | 7 |
| **Torpedoes (TORP)** Source classes associated with active acoustic signals produced by torpedoes | TORP2 | Heavyweight torpedo (e.g., MK 48) | I | 0 | 0 |

Notes: H = hours; I = 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 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 TMAA.
- 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 3.0-4: 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 3.0-4: Sonar and Transducers Qualitatively Analyzed

| Source Class Category | Bin | Characteristics |
|---|---|---|
| **Tracking Pingers (P):** Devices that send a ping to identify an object location | P2 | • low duty cycles (single pings in some cases)<br>• short pulse lengths (typically 20 milliseconds)<br>• low source levels |

#### 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 TMAA. 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).

Anti-submarine warfare surface platforms are much quieter than Navy oil tankers, for example, which have a smaller presence but contribute substantially more broadband noise (Mintz & Filadelfo, 2011). A variety of smaller craft that vary in size and speed, such as service vessels for routine operations and opposition forces used during training events, would be operating within the TMAA as well.

The quietest Navy warships radiate much less broadband noise than a typical fishing vessel, while the loudest Navy ships during travel are almost on par with large oil tankers (Mintz & Filadelfo, 2011). The average acoustic signature for a Navy vessel is 163 dB re 1 µPa, while the average acoustic signature for a commercial vessel is 175 dB re 1 µPa (Mintz & Filadelfo, 2011). Typical large vessel ship-radiated noise is dominated by tonals related to blade and shaft sources at frequencies below 50 Hz and by broadband components related to cavitation and flow noise at higher frequencies (approximately around the one-third octave band centered at 100 Hz) (MacGillivray et al., 2019; Mintz & Filadelfo, 2011; Richardson et al., 1995; Urick, 1983). Ship types also have unique acoustic signatures characterized by differences in dominant frequencies. Bulk carrier noise is predominantly near 100 Hz while container ship and tanker noise is predominantly below 40 Hz (McKenna et al., 2012). Small craft will emit higher-frequency noise (between 1 kHz and 50 kHz) than larger ships (below 1 kHz). Sound produced by vessels will typically increase with speed (MacGillivray et al., 2019; Wladichuk et al., 2019).

The Center for Naval Analyses conducted studies to determine traffic patterns of Navy and non-Navy vessels (Mintz, 2012; Mintz, 2016; Mintz & Filadelfo, 2011; Mintz & Parker, 2006). 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 feet (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, 2012; Mintz & Filadelfo, 2011).

Although the aforementioned studies did not include analysis of vessel traffic and associated vessel noise in the TMAA, the conclusions of the studies are relevant to vessel noise in the TMAA. Overall, the contribution of Navy vessel traffic to broadband noise levels was relatively small compared with the contribution from commercial vessel traffic.

#### 3.0.4.1.3 Aircraft Noise

Fixed-wing, tiltrotor, and rotary-wing aircraft are used for a variety of training activities throughout the TMAA, 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 B, Acoustic and Explosive Concepts). Aircraft used in training 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 and noise levels can vary due to different aircraft and engine types, speeds, heights, and angles (Erbe et al., 2018). Perception of aircraft noise can vary between marine species based on different hearing sensitivities (Erbe et al., 2018). Aircraft may transit to or from vessels at sea throughout the TMAA from established airfields on land. The majority of aircraft noise would be generated at air stations, which are outside the TMAA. Takeoffs and landings occur at established airfields as well as on vessels at sea across the TMAA. 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 3.0-5 provides source levels for some typical aircraft used during training in the TMAA 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

Sound generated in air is transmitted to water primarily in a narrow area directly below the source Appendix B (Acoustic and Explosive Concepts). A sound wave propagating from any source must enter the water at an angle of incidence of about 13° or less from the vertical for the wave to continue propagating under the water's surface. At greater angles of incidence, the water surface acts as an effective reflector of the sound wave and allows very little penetration of the wave below the water (Urick, 1983). Water depth and bottom conditions strongly influence how the sound from airborne sources propagates underwater. At lower altitudes, sound levels reaching the water surface would be higher, but the transmission area would be smaller. As the sound source gains altitude, sound reaching the water surface diminishes, but the possible transmission area increases. Estimates of underwater sound pressure level are provided for representative aircraft in Table 3.0-5.

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

### Table 3.0-5: 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] |
| F-35A Under Military Power | 145 dBA re 20 µPa at 13 m from source[3] |
| F-35A 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 $\mu Pa^2s$[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 $\mu Pa^2s$[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 $\mu Pa^2s$ = 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).

#### 3.0.4.1.3.2 Helicopters

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

Helicopter unit level training typically entails single-aircraft sorties over water that start and end at an air station, although flights may occur from ships at sea. Individual flights typically last about two to four hours. Some events require low-altitude flights over a defined area, such as ASW Tracking Exercise – Helicopter. Most helicopter sorties associated with ASW Tracking Exercise – Helicopter would occur at altitudes as low as 50 ft.

#### 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. 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, 2017b), 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 miles (mi.) 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 mi. 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 mi. for each 1,000 ft. of altitude. For example, an aircraft flying supersonic, straight and level at 50,000 ft. can produce a sonic boom carpet about 50 mi. wide. The sonic boom, however, would not be uniform, and its intensity at the water surface would decrease with greater aircraft altitude. Maximum intensity is directly beneath the aircraft and decreases as the lateral distance from the flight path increases until shock waves refract away from the ground or water surface and the sonic boom attenuates. The lateral spreading of the sonic boom depends only on altitude, speed, and the atmosphere and is independent of the vehicle's shape, size, and weight. The ratio of the aircraft length to maximum cross-sectional area also influences the intensity of the sonic boom. The longer and slenderer the aircraft, the weaker the shock waves. The wider and more blunt the aircraft, the stronger the shock waves can be (U.S. Department of the Navy & Department of Defense, 2007).

In air, the energy from a sonic boom is concentrated in the frequency range from 0.1 to 100 Hz. The underwater sound field due to transmitted sonic boom waveforms is primarily composed of low-frequency components (Sparrow, 2002), and frequencies greater than 20 Hz have been found to be difficult to observe at depths greater than 33 ft. (10 m) (Sohn et al., 2000). F/A-18 Hornet supersonic flight was modeled to obtain peak sound pressure levels (SPLs) and energy flux density at the water surface and at depth (U.S. Department of the Air Force, 2000). These results are shown in Table 3.0-6.

### Table 3.0-6: Sonic Boom Underwater Sound Levels Modeled for F/A-18 Hornet Supersonic Flight

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

[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 µPa$^2$-s = decibel(s) referenced to 1 micropascal squared seconds, m = meter(s).

#### 3.0.4.1.4 Weapon Noise

The Navy trains using a variety of weapons, as described in Appendix A (Navy 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) below.

Examples of some types of weapon noise are shown in Table 3.0-7. Examples of launch noise are provided in the table. Noise produced by other weapons and devices is described further below.

### Table 3.0-7: 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

Firing a gun produces a muzzle blast in air that propagates away from the gun with strongest directivity in the direction of fire (Figure 3.0-2). Because the muzzle blast is generated at the gun, the noise decays with distance from the gun. The muzzle blast has been measured for the largest gun analyzed in this SEIS/OEIS, the 5-inch large caliber naval gun. At a distance of 3,700 ft. from the gun, which was fired at 10 degrees elevation angle, and at 10 degrees off the firing line, the in-air received level was 124 dB re 20 µPa SPL peak for the atmospheric conditions of the test (U.S. Department of the Navy, 1981). Measurements were obtained for additional distances and angles off the firing line but were specific to the atmospheric conditions present during the testing.

**Figure 3.0-2: Gun Blast and Projectile from a MK 45 MOD 2 5-inch/54 Caliber Navy Gun on a Cruiser (top), a MK 45 MOD 2 5-inch/54 Caliber Navy Gun on a Destroyer (bottom left), and a MK 45 MOD 4 5-inch/62 Caliber Navy Gun on a Destroyer (bottom right)**

As the pressure from the muzzle blast from a ship-mounted large caliber gun propagates in air toward the water surface, the pressure can be both reflected from the water surface and transmitted into the water. As explained in Appendix B (Acoustic and Explosive Concepts), most sound enters the water in a narrow cone beneath the sound source (within about 13–14 degrees of vertical), with most sound outside of this cone being totally reflected from the water surface. In-water sound levels were measured during the muzzle blast of a 5-inch large caliber naval gun. The highest possible sound level in the water (average peak SPL of 200 dB re 1 µPa, measured 5 ft. below the surface) was obtained when the gun was fired at the lowest angle, placing the blast closest to the water surface (Yagla & Stiegler, 2003). The unweighted SEL would be expected to be 15–20 dB lower than the peak pressure, making the highest possible SEL in the water about 180 to 185 dB re 1 µPa squared seconds (dB re 1 µPa $^{2}$-s) directly below the muzzle blast. Configuration of the 5-inch gun on U.S. Navy ships also affects how sound from each muzzle blast could enter the water. On cruisers, when swung out to either side, the barrel of the gun extends beyond the ship deck and over water. On destroyers, when swung out to either side, the barrel of the gun is still over the ship's deck (Figure 3.0-2). Other gunfire arrangements, such as with smaller-caliber weapons or greater angles of fire, would result in less sound entering the water. The sound entering the water would have the strongest directivity directly downward beneath the gun blast, with lower sound pressures at increasing angles of incidence until the angle of incidence is reached where no sound enters the water.

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

#### 3.0.4.1.4.2 Supersonic Projectile Bow Shock Wave

Supersonic projectiles, such as a fired gun shell, 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 B [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 degrees) 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-inch/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-inch projectile shock wave ranged from 140 to 147 dB re 20 µPa SPL peak taken at the ground surface at 0.59 nautical miles distance from the firing location and 10 degrees off the line of fire for safety (approximately 190 m from the shell’s trajectory) (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

Missiles can be rocket or jet propelled, and launches typically occur far offshore in special use airspace such as warning areas, air traffic control assigned airspace, and restricted areas. Sound due to missile and target launches is typically at a maximum at initiation of the booster rocket. It rapidly fades as the missile or target reaches optimal thrust conditions and the missile or target reaches a downrange distance where the booster burns out and the sustainer engine continues. Examples of launch noise sound levels are shown in Table 3.0-7.

#### 3.0.4.1.4.4 Impact Noise (Non-Explosive)

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

### 3.0.4.2 Explosive Stressors

This section describes the characteristics of explosions during naval training. The activities analyzed in this SEIS/OEIS that use explosives are described in Appendix A (Navy Activities Descriptions). This section provides the basis for analysis of explosive impacts on fish, marine mammals, and birds in the remainder of this chapter. Explanations of the terminology and metrics used when describing explosives in this SEIS/OEIS are in Appendix B (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 B (Acoustic and Explosive Concepts).

#### 3.0.4.2.1 Explosions in Water

In-water explosive detonations during training activities are associated with explosives, including bombs and naval gun shells. For purposes of the analysis for in-water explosives, detonations occurring in air at a height of 33 ft. (10 m) or less above the water surface, and detonations occurring directly on the water surface were modeled to detonate at a depth of 0.3 ft. (0.1 m) below the water surface since there is currently no means to model impacts from in-air detonations. Additional information regarding energy transmission from detonations is discussed in Appendix B (Acoustic and Explosive Concepts). 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 activities using explosives that could detonate in water or near 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 or near the water surface are binned by net explosive weight. The bins of explosives that are proposed for use in the TMAA are shown in Table 3.0-8. This table shows the number of explosive items that could be used in any year under Alternative 1 for training activities.

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 B (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 TMAA.

### Table 3.0-8: Explosive Sources Used During Training in the Temporary Maritime Activities Area

| Explosives (Source Class and Net Explosive Weight) (lb.) | Number of Explosives with the Proposed Action | Representative Underwater Detonation Depth[1] |
|---|---|---|
| E5 (> 5–10 lb. NEW) | 112 | 0.3 ft. (0.1 m) |
| E9 (> 100–250 lb. NEW) | 142 | 0.3 ft. (0.1 m) |
| E10 (> 250–500 lb. NEW) | 32 | 0.3 ft. (0.1 m) |
| E12 (> 650–1,000 lb. NEW) | 4 | 0.3 ft. (0.1 m) |

[1] Underwater detonation depths listed are those assumed for purposes of acoustic impacts modeling. Detonations assumed to occur at a depth of 0.3 ft. (0.1 m) include detonations that would actually occur at or near the water surface.

Notes: m = meters, NEW = Net Explosive Weight, ft. = feet, lb. = pounds.

#### 3.0.4.2.2 Explosions in Air

Explosions in air include detonations of projectiles and missiles during surface-to-air gunnery and air-to-air missile exercises conducted during air warfare. These explosions typically occur far above the water surface in special use airspace. Some typical types of explosive munitions that would be detonated in air during Navy activities are shown in 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 (Navy Activities Descriptions) describes where activities with these stressors typically occur.

The explosive energy released by detonations in air has been well studied (see Appendix B, 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 would not result in other propelled materials such as crater debris.

Table 3.0-9. Various missiles, rockets, and medium- and large-caliber projectiles may be explosive or non-explosive, depending on the objective of the training activity in which they are used.

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 (Navy Activities Descriptions) describes where activities with these stressors typically occur.

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**Table 3.0-9: Typical Air Explosive Munitions During Navy Activities**

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

[1] Mission Design Series and popular name shown for missiles.

[2] Most medium and large caliber projectiles used during Navy training 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.

### 3.0.4.3 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, which can be either temporary or permanent and may be limited to a narrow frequency range of hearing.*
- ***Masking*** *- When the perception of a biologically important sound (i.e., signal) is interfered with by a second sound (i.e., noise).*
- ***Physiological stress*** *- An adaptive process that helps an animal cope with changing conditions; however, 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.

Sounds emitted from a sound-producing activity (Box A1) travel through the environment to create a spatially variable sound field. The received sound at 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 predicted 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).

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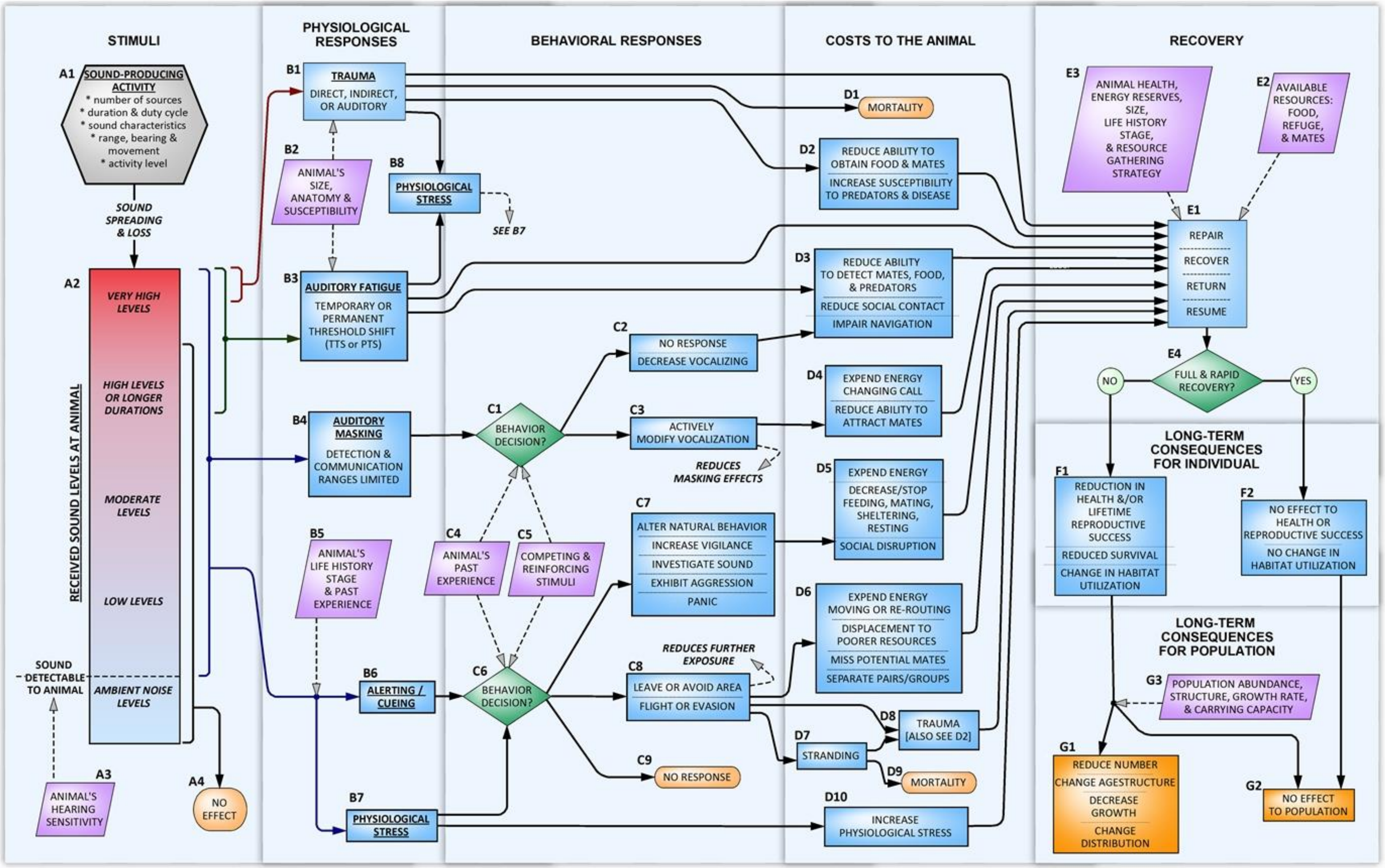

Figure 3.0-3: Flow Chart of the Evaluation Process of Sound-Producing Activities

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#### 3.0.4.3.1 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 et al., 2005; Crum & Mao, 1996); 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 or 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.

#### 3.0.4.3.2 Hearing Loss

Hearing loss, also called a noise-induced threshold shift, is possibly the best 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.

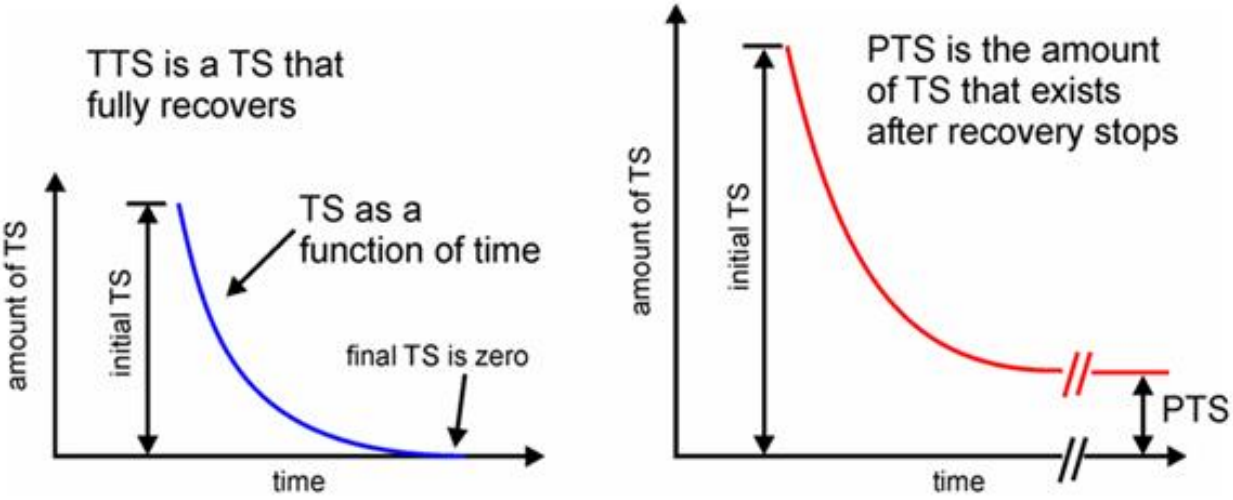

**Figure 3.0-4: Two Hypothetical Threshold Shifts**

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

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

The relationship between TTS and PTS is complicated and poorly understood, even in humans and terrestrial mammals, where numerous studies failed to delineate a clear relationship between the two. Relatively small amounts of TTS (e.g., less than 40–50 dB measured two minutes after exposure) will recover with no apparent permanent effects; however, terrestrial mammal studies revealed that larger amounts of threshold shift can result in permanent neural degeneration, despite the hearing thresholds returning to normal (Kujawa & Liberman, 2009). The amounts of threshold shift induced by Kujawa and Liberman (2009) were described as being "at the limits of reversibility." It is unknown whether smaller amounts of threshold shift can result in similar neural degeneration, or if effects would translate to other species such as marine animals.

Hearing loss can increase an animal's physiological stress (Box B8), which feeds into the stress response (Box B7). Hearing loss can increase 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.

#### 3.0.4.3.3 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.

#### 3.0.4.3.4 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 at the animal (Box A2), the details of the sound-producing activity (Box A1), the animal's life history stage (e.g., juvenile or adult, breeding or feeding season), 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.

#### 3.0.4.3.5 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 vehicles 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).

#### 3.0.4.3.6 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 increases 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 carrying 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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