Post-Model Quantitative Analysis of Animal Avoidance Behavior and Mitigation Effectiveness for Northwest Training and Testing Activities

Technical Report

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1. INTRODUCTION

The Navy's *Northwest Training and Testing Activities Final Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS)* (U.S. Department of the Navy 2015) quantitatively assesses potential impacts to marine mammals and sea turtles due to exposure to sonar, other active acoustic sources, and explosives. The quantitative analysis of acoustic and explosive impacts on marine mammals consists of two components: (1) acoustic modeling of exposures and (2) post-model analysis. The first component, acoustic modeling of exposures, is described in the Navy technical report titled *Determination of Acoustic Effects on Marine Mammals and Sea Turtles for the Northwest Training and Testing Environmental Impact Statement/ Overseas Environmental Impact Statement* (Marine Species Modeling Team 2014), available at www.NWTTEIS.com, and are hereafter referred to as the model and the modeling technical report, respectively. The second component described herein, post-model analysis, quantitatively accounts for animal avoidance behavior based on best available science and implementation of mitigation to avoid or reduce acoustic exposures during Navy training and testing activities. Together, the acoustic modeling and post-model analysis provide the Navy's best estimate of quantitative acoustic impacts based on current available methodologies that, along with consideration of actual observation data during past Navy training and testing activities and best available science regarding marine species, informs the comprehensive analysis of impacts to marine species presented in the *Northwest Training and Testing Final EIS/OEIS* (U.S. Department of the Navy 2015).

A basic understanding of the modeling of acoustic and explosive exposures undertaken for the *Northwest Training and Testing Final EIS/OEIS* is necessary to understand the purpose of the subsequent post-model analysis to account for animal avoidance behavior and implementation of mitigation (a detailed explanation can be found in the modeling technical report). The acoustic modeling assesses various scenarios that represent typical training and testing activities in typical locations and seasons in the Study Area, and takes into account predicted animal densities and environmental factors that affect sound propagation. The modeling considers the synergistic effects of multiple acoustic sources in a single event and tracks the acoustic exposure history of each animat (a dosimeter representing an animal) in the affected area. The exposure history of each animat is compared to acoustic impact thresholds to determine the worse-case acoustic effect assigned to that animat. Acoustic impact criteria and thresholds are provided in the Navy technical report *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis* (Finneran and Jenkins 2012) available at www.NWTTEIS.com. The predicted numbers of impacts on each species for each testing and training activity are summed to provide the overall model-estimated effects. The term "model-estimated effects" is used throughout this document to refer to the model results without any further post-model analysis.

As described in the modeling technical report, the model accounts for an animat's position vertically in the water column by taking into account species-specific dive profiles; however, it does not account for an animat's horizontal movement, so the model assumes that an animal would remain stationary and tolerate repeated intense sound exposures at very close distances. This assumption is invalid because animals are likely to leave the area to avoid intense sound exposure that could cause injury. Similarly, the modeling assumes that certain species known to avoid areas of high anthropogenic activity would remain in the very close vicinity of all Navy training and testing activities, regardless of how many vessels or low-flying aircraft (i.e., helicopters) are involved. The outputs of the model, therefore, present an unrealistically high estimate of acoustic impacts in close proximity to certain Navy training and testing activities.

Additionally, the modeling currently does not account for implementation of mitigation designed to avoid or reduce marine mammal exposures to explosives and high intensity sound, nor does it account for standard operating procedures (procedures designed for the safety of personnel and equipment) implemented to ensure safety and mission success, but which may have incidental environmental benefits. That is, the modeling assumes that any mitigations measures, such as sonar power-down or delay of a detonation, would not be implemented even if an animal could be sighted within the mitigation zone. The Navy's proposed mitigations were developed in cooperation with the National Marine Fisheries Service (NMFS) and are effective at reducing environmental impacts while being operationally feasible. The outputs of the model, therefore, present an unrealistically high estimate of acoustic impacts within the mitigation zones of certain Navy training and testing activities.

In order to provide a holistic quantitative assessment of acoustic impacts, the post-model analysis quantitatively assessed the effect of animal avoidance behavior and implementation of mitigation, considering the following:

- Best available science on species' behavior
- Number of platforms (i.e., aircraft, vessels) used during specific activities
- Ability to detect specific species
- Ability to observe the mitigation zone around different platforms during different activities

The following sections explain each of the post-model analysis considerations (pre-activity area avoidance by sensitive species, implementation of mitigation, and during activity avoidance of intense sound exposures). The steps of the post-model analysis are briefly summarized in Table 1-1 and presented in the order they are expected to occur during an actual training or testing activity, which is also the order in which they were mathematically considered in the post-model analysis. When feasible for a given activity, mitigation begins prior to the actual production of underwater sound (e.g., 10-30 minutes, dependent upon platform, prior to most sonar and explosive activities); therefore, mitigation effectiveness is applied in the post-model analysis before animal avoidance is quantified. The results of the post-model analysis are shown for each species in Section 5 (Summary) with estimated effects to marine species for each training and testing activity grouped and summed as they are in the *Northwest Training and Testing Activities Final EIS/OEIS*[1]. Section 5 (Summary) shows the original model outputs and the reductions in impacts due to each step of the post-model analysis for training and testing activities proposed under the *Northwest Training and Testing Draft EIS/OEIS* preferred alternative (Alternative 1). Any reductions in model-estimated mortalities or injuries due to the post-model analysis are not removed from the overall sum of quantitative impact; in all cases, any reductions were added to the next highest-order impact (e.g., reductions in injury were added to temporary threshold shift [TTS]). The resulting quantitative assessment of acoustic impacts is still assumed to be conservative (i.e., over-predicted).[2]

[1] Estimated effects for activities that reoccur annually are summed for all training and all testing activities, respectively. See Chapter 2 of the *Northwest Training and Testing Final EIS/OEIS* for a description of the activities that compose annual training and annual testing. Estimated effects from activities that do not reoccur annually (e.g., Civilian Port Defense) are presented in their own tables.

[2] Conservative assumptions are explained in Section 3.4.3.1.14.4 (Model Assumptions and Limitations) of the Final *EIS/OEIS for Northwest Training and Testing* (U.S. Department of the Navy 2015). In brief, they include: (1) animats are modeled as being underwater and facing the source and, therefore, always predicted to receive the maximum sound level at their position within the water column; (2) multiple exposures within any 24-hour period are considered one continuous exposure for the purposes of calculating the temporary or permanent hearing loss, because there are not sufficient data to estimate a hearing recovery function for the time between exposures; (3) explosive thresholds for onset mortality and onset slight lung injury are set on the threshold of effect for 1 percent likelihood for a calf-weight animal; and (4) animats are assumed to receive the full impulse of the initial positive pressure wave due to an explosion, although the impulse-based thresholds (onset mortality and onset slight lung injury) assume an impulse delivery time adjusted for animal size and depth.

Table 1-1: Post-Model Acoustic Impact Analysis Process

<table>
<tr><th colspan="2">Is the Sound Source Sonar/Other Active Acoustic Source or Explosives?</th></tr>
<tr><th>Sonar and Other Active Acoustic Sources</th><th>Explosives</th></tr>
<tr><td>S-1. Is the activity preceded by multiple vessel activity or hovering helicopter (local transits and event preparation prior to sonar use)? (discussed in Section 2)</td><td>E-1. Is the activity preceded by multiple vessel activity or hovering helicopter (local transits and event preparation prior to explosive use)? (discussed in Section 2)</td></tr>
<tr><td>Species sensitive to human activity (i.e., harbor porpoises and beaked whales) are assumed to avoid the activity area before the use of sonar, putting them out of the range to PTS. The model-estimated PTS to these species during these activities are unlikely to actually occur and, therefore, are considered to be TTS (animal is assumed to move into the range of potential TTS).

The activities preceded by multiple vessel movements or hovering helicopters are listed in Table 2-1.</td><td>Species sensitive to human activity (i.e., harbor porpoises and beaked whales) are assumed to avoid the activity area before the use of explosives, putting them out of the range to mortality. Model-estimated mortalities to these species during these activities are unlikely to actually occur and, therefore, are considered to be injuries (animal is assumed to move into the range of potential onset of slight lung injury).

The activities preceded by multiple vessel movements or hovering helicopters are listed in Table 2-2.</td></tr>
<tr><td>S-2. Can Lookouts observe the activity-specific mitigation zone up to and during the sound-producing activity? (discussed in Section 3)</td><td>E-2. Can Lookouts observe the activity-specific mitigation zone up to and during the sound-producing activity? (discussed in Section 3)</td></tr>
<tr><td>If Lookouts are able to observe the mitigation zone up to and during a sound-producing activity, the sound-producing activity would be halted or delayed if a marine mammal is observed and would not resume until the animal is thought to be out of the mitigation zone (per the mitigation measures in Chapter 5 of the EIS/OEIS for Northwest Training and Testing). Therefore, model-estimated PTS exposures are reduced by the portion of animals that are likely to be seen [Mitigation Effectiveness (1, 0.5, or 0) x Sightability, g(0)]. Any animals removed from the model-estimated PTS are instead assumed to be TTS (animal is assumed to move into the range of TTS).

The Mitigation Effectiveness values for activities using sonar or other active acoustic sources are provided in Table 3-2. The g(0) value is associated with the platform (vessel or aircraft) with the dedicated Lookout(s). The g(0) values are provided in Table 3-4.</td><td>If Lookouts are able to observe the mitigation zone up to and during an explosion, the explosive activity would be halted or delayed if a marine mammal is observed and would not resume until the animal is thought to be out of the mitigation zone (per the mitigation measures in Chapter 5 of the Northwest Training and Testing EIS/OEIS). Therefore, model-estimated mortalities and injuries (onset slight lung injury and PTS) are reduced by the portion of animals that are likely to be seen [Mitigation Effectiveness (1, 0.5, or 0) x Sightability, g(0)]. Any animals removed from the model-estimated mortalities or injuries (onset slight lung injury or PTS) are instead assumed to be injuries (Onset slight lung injury) or behavioral disturbances (TTS), respectively (animals are assumed to move into the range of a lower effect).

The Mitigation Effectiveness values for explosive activities are provided in Table 3-3. The g(0) value is associated with the platform (vessel or aircraft) with the dedicated Lookout(s). The g(0) values are provided in Table 3-4.</td></tr>
<tr><td>S-3. Does the activity cause repeated sound exposures which an animal would likely avoid? (discussed in Section 4)</td><td>E-3. Does the activity cause repeated sound exposures which an animal would likely avoid? (discussed in Section 4)</td></tr>
<tr><td>The Navy Acoustic Effects Model assumes that animals do not move away from a sound source and receive a maximum sound exposure level. In reality, an animal would likely avoid repeated sound exposures that would cause PTS by moving away from the sound source. Therefore, only the initial exposures resulting in model-estimated PTS to high-frequency cetaceans, low frequency cetaceans, phocids, otariids, mustelids, and sea turtles are expected to actually occur (after accounting for mitigation in step S-2). Model estimates of PTS beyond the initial pings are considered to actually be TTS, as the animal is assumed to move out of the range to PTS and into the range of TTS.

Marine mammals in the mid-frequency hearing group would have to be close to the most powerful moving source (less than 10 m) to experience PTS. These model-estimated PTS exposures of mid-frequency cetaceans are unlikely to actually occur and, therefore, are considered to be TTS (animal is assumed to avoid PTS and move into the range of TTS).</td><td>The Navy Acoustic Effects Model assumes that animals do not move away from multiple explosions and receive a maximum sound exposure level. In reality, an animal would likely avoid repeated sound exposures that would cause PTS by moving away from the site of multiple explosions. Therefore, only the initial exposures resulting in model-estimated PTS are expected to actually occur (after accounting for mitigation in step E-2). Model estimates of PTS are reduced to account for animals moving away from an area with multiple explosions, out of the range to PTS, and into the range of TTS.

Activities with multiple explosions are listed in Table 4-8.</td></tr>
</table>

2. HARBOR PORPOISE AND BEAKED WHALE AVOIDANCE OF AREAS OF HIGH ACTIVITY PRIOR TO USE OF SONAR, OTHER ACTIVE ACOUSTIC SOURCES, OR EXPLOSIVES

- Species: harbor porpoises (*Phocoena phocoena*) and beaked whales (family: Ziphiidae)
- Activities/ Sources: Only naval activities preceded by movements of multiple vessels or hovering aircraft
- Impact Zone (sonar and other active acoustic sources): Range to permanent threshold shift (PTS)
- Impact Zone (explosives): Range to onset mortality
- Post-Model Acoustic Impact Analysis Process step (from Table 1-1): S-1 and E-1

2.1 BACKGROUND

Some marine mammals may avoid sound exposures by avoiding areas with high levels of anthropogenic activity, such as multiple ships in transit or hovering aircraft. Navy ships do not intentionally approach or follow marine mammals and are generally not expected to elicit avoidance or alarm behavior, except for certain sensitive species (e.g., harbor porpoises and beaked whales). Cues preceding the commencement of a naval activity that will use sonars or explosives (e.g., multiple vessel presence and movement, aircraft overflight) may result in some animals departing the immediate area before commencement of sonar or explosive activity. Harbor porpoises and beaked whales have been observed to be more sensitive to human activity than other marine mammal species.

2.1.1 HARBOR PORPOISES

Research has shown that harbor porpoises are sensitive to the presence of human activity. Finless porpoises (Li et al. 2008) and harbor porpoises (Barlow et al. 1988; Evans et al. 1994; Palka and Hammond 2001; Polacheck and Thorpe 1990) routinely avoid and swim away from large motorized vessels. The vaquita, which is closely related to the harbor porpoise in the Study Area, appears to avoid large vessels at about 2,995 ft. (913 m) (Jaramillo-Legorreta et al. 1999). The assumption is that the harbor porpoise would respond similarly to large Navy vessels.

The behavioral sensitivity of this species is acknowledged within the Navy's criteria and thresholds to assess potential acoustic impacts by the use of a low step-function of 120 dB re 1 µPa to assess behavioral reactions when exposed to sounds, based on observations of both wild (Johnston 2002) and captive (Kastelein et al. 2000; Kastelein et al. 2005b) harbor porpoises.

2.1.2 BEAKED WHALES

Research has also shown that beaked whales are sensitive to the presence of human activity. Beaked whales have been documented to exhibit avoidance of human activity or respond to vessel presence (Pirotta et al. 2012). Most beaked whales were observed to react negatively to survey vessels or low-altitude aircraft by quick diving and other avoidance maneuvers, and none were observed to approach vessels (Wursig et al. 1998).

The behavioral sensitivity of these species is already acknowledged within the Navy's criteria and thresholds to assess potential acoustic impacts by the use of a low step-function of 140 dB re 1 µPa to assess behavioral reactions when exposed to sounds, based on observations of wild animals (McCarthy et al. 2011; Tyack et al. 2011).

2.2 POST-MODEL ANALYSIS

The model estimates of impacts are based on horizontally static animats; sensitive species, specifically harbor porpoises and beaked whales, were modeled as though they would tolerate very close encounters with vessels and low-flying aircraft. As a result, the model predicts unrealistically high numbers of impacts to these species at close ranges. Based on research and observations showing that harbor porpoises and beaked whales are likely to react to human activity by maintaining distance or exhibiting active avoidance, the post-model analysis assumed that harbor porpoises and beaked whales would avoid close interactions with certain Navy training and testing activities with multiple vessels and low flying aircraft. However, it was assumed that harbor porpoises and beaked whales would not move away from Navy training and testing activities before the start of sound-producing activities if an activity did not use multiple vessels or hovering aircraft.

Per the post-model analysis, harbor porpoises and beaked whales are assumed to avoid a portion of the activity area closest to vessels and hovering aircraft prior to the start of sound-producing activities listed in Table 2-1 (activities using sonar and other active acoustic sources) and Table 2-2 (activities using explosives). To be conservative and account for uncertainty, the post-model analysis assumed the area of avoidance would be the region encompassing onset PTS (for the activities using sonar and other active acoustic sources) and the region encompassing onset mortality (for the activities using explosives). The assumed avoidance ranges are small compared to the distances at which these species have been observed to avoid human interaction. In the Offshore portion of the Study Area for example:

- for the most powerful naval sonar for which harbor porpoise and beaked whale human activity avoidance was analyzed, the AN/SQS-53, the single ping ranges to onset PTS are approximately:
  - 100 m for harbor porpoises (a high-frequency cetacean)
  - 10 m for beaked whales (mid-frequency cetaceans)
- for the largest explosive for which harbor porpoise and beaked whale human activity avoidance was analyzed, bin E12 (>650-1000 lb. net explosive weight), the average ranges to onset mortality for a calf-sized animal are approximately:
  - 215 m for Dall's porpoises (a high-frequency cetacean)
  - 200 m for beaked whales (mid-frequency cetaceans)

Actual ranges to onset mortality would usually be substantially less for the explosive activities listed in Table 2-2 because charge sizes would be smaller and most animals would not be calf-sized (i.e., the impulse necessary for onset mortality increases with animal size).

For the Navy training and testing activities preceded by high levels of activity, the following post-model refinements were made:

- Activities using sonar and other active acoustic sources (Table 2-1):
  - Harbor porpoises and beaked whales modeled within the range to onset PTS are assumed to avoid the region close to the sound source prior to the beginning of sound producing activities.
  - Harbor porpoise and beaked whales modeled within the range to onset PTS are assumed to move within the range of onset TTS (i.e., model-estimated PTS were added to the model-estimated TTS); therefore, although some of the predicted impacts are re-categorized, the overall number of animals predicted to be affected is unchanged.

- Activities using explosives (Table 2-2):
    - Harbor porpoises and beaked whales modeled within the range to onset mortality are assumed to avoid the region close to the detonation area prior to the detonation.
    - Harbor porpoise and beaked whales modeled within the range to onset mortality are assumed to move within the range to onset slight lung injury (i.e., recoverable injury; model-estimated mortalities were added to the model-estimated slight lung injuries); therefore, although some of the predicted impacts are re-categorized, the overall number of animals predicted to be affected is unchanged.

Table 2-1: Activities Using Sonar and Other Active Acoustic Sources Preceded by Multiple Vessel Movements or Hovering Helicopters

ACTIVITY[1]	DESCRIPTION OF NAVY PRESENCE PRECEDING ACTIVITY
Training	
Maritime Homeland Defense/Security Mine Countermeasures Integrated Exercise	Multiple small boats or a helicopter present.
Tracking Exercise -Helicopter	Helicopter present.
Testing	
Anti-Submarine Warfare Mission Package Testing	Helicopter and surface vessel present.
Cold Water Training	Multiple small boats or single small boat with stationary platform and divers present.
Component System Testing	Single or multiple small boats with unmanned underwater vehicles, towed platforms or anchored targets present.
Countermeasure Testing	Multiple vessels or single vessel present (0.5 value given).
System, Subsystem, and Component Testing – Pierside Acoustic Testing	Vessel and unmanned underwater vehicle present.
System, Subsystem, and Component Testing - Development Training and Testing	Vessel and unmanned underwater vehicle present.
Torpedo Exercise (all)	Vessel and unmanned underwater vehicle or helicopter present.
Torpedo (Explosive) Testing	Vessel, submarine, or aircraft present (0.5 value given).
Unmanned Underwater Vehicle Testing (all)	Multiple vessels and unmanned underwater vehicles present.
Underwater Vessel Acoustic Measurement (all)	Small boat and surface or underwater vessel present.

[1] The potential for sensitive species to avoid areas near naval activity before use of sonar or other active acoustic sources was only quantified for the activities listed in this table. The potential for other training and testing activities to elicit these behaviors was not quantified, and model-estimated impacts for activities not listed here were not adjusted for pre-activity avoidance behavior.

Table 2-2: Activities Using Explosives Preceded by Multiple Vessel Movements or Hovering Helicopters

ACTIVITY[1]	DESCRIPTION OF NAVY PRESENCE PRECEDING ACTIVITY
Training	
Mine Neutralization – Explosive Ordnance Disposal	Multiple vessels present, sometimes helicopter present as well, in addition to target setup.
MISSILEX [Air-to-Surface]	Target setup by support vessel.
Sinking Exercise	Multiple vessels and aircraft present.
Testing	
Torpedo (Explosive) Testing	Target setup by support vessel.

[1] The potential for sensitive species to avoid areas near naval activity before use of explosives was only quantified for the activities listed in this table. The potential for other training and testing activities to elicit these behaviors was not quantified, and model-estimated impacts for activities not listed here were not adjusted for pre-activity avoidance behavior.

3. REDUCING ACOUSTIC EXPOSURES BY IMPLEMENTATION OF MITIGATION

- Species: all modeled cetacean & pinniped species
- Activities/ Sources: Training or testing activities for which, at a minimum, over half the mitigation zone can be continuously observed or the entire mitigation zone can be observed for the majority of the scenarios.
- Impact Zone (sonar and other active acoustic sources): Range to permanent threshold shift (PTS)
- Impact Zone (explosives): Range to onset mortality, range to slight lung injury, and range to PTS
- Post-Model Acoustic Impact Analysis Process step (from Table 1-1): S-2 and E-2

3.1 BACKGROUND

Mitigation measures are designed to help reduce or avoid potential impacts on marine resources. The mitigation measures proposed to be implemented during training and testing activities are described in Chapter 5 (Standard Operating Procedures, Mitigation, and Monitoring) of the *Northwest Training and Testing Activities Final EIS/OEIS* (U.S. Department of the Navy 2015). Development of mitigation measures has been coordinated with the NMFS and the U.S. Fish and Wildlife Service through the consultation and permitting processes under the Endangered Species Act and Marine Mammal Protection Act.

Mitigation measures implemented during use of sonar, other active acoustic sources, and explosives typically include the use of Lookouts. Lookouts have multiple observation objectives, which include but are not limited to detecting the presence of biological resources and recreational or fishing boats, observing mitigation zones, and monitoring for vessel and personnel safety concerns. Mitigation zones are designed solely for the purpose of reducing potential impacts on marine mammals and sea turtles from training and testing activities. Mitigation zones are measured as the radius from a sound source. Unique to each activity category, each radius represents a distance that the Navy will visually observe to help reduce injury to marine species. Visual detections of applicable marine species will be communicated immediately to the appropriate watch station for information dissemination and appropriate action. Mitigation measures include powering down, halting, or delaying use of a sound source or explosives when marine mammals are observed in the mitigation zone.

The Navy developed each recommended mitigation zone to avoid or reduce the potential for onset of the lowest level of injury, permanent threshold shift (PTS. For explosive activities, mitigating to the predicted maximum range to PTS consequently mitigates to the predicted maximum range to onset mortality, onset slight lung injury, and onset slight gastrointestinal tract injury, since the maximum range to effects for these effects are shorter than for PTS. Furthermore, in most cases, the predicted maximum range to PTS also consequently covers the predicted average range to TTS. Table 3-1 summarizes the predicted average range to TTS, average range to PTS, maximum range to PTS, and recommended mitigation zone for each activity category, based on the Navy's acoustic propagation modeling results for the most sensitive marine mammal functional hearing group. In order to have consistent mitigation zones for the Navy's sailors, the recommended mitigation zones are based on the largest maximum range to PTS across all of the Navy's training and testing areas for each activity. Therefore, in some cases the mitigation zones shown in Table 3-1 cover a much larger area than the reported maximum range to PTS for activities that occur in the Northwest Training and Testing Study Area.

Table 3-1: Predicted Range to Effects in Study Area and Recommended Mitigation Zones

Activity Category	Representative Source (Bin)[1]	Predicted Average Range to TTS	Predicted Average Range to PTS	Predicted Maximum Range to PTS	Recommended Mitigation Zone
Non-Impulsive Sound					
Low-Frequency and Hull-Mounted Mid-Frequency Active Sonar	SQS-53 ASW hull-mounted sonar (MF1)	4,251 yd. (3,887 m) for one ping	100 yd. (91 m) for one ping	Not applicable	Training: 1,000 yd. (914 m) and 500 yd. (457 m) power downs and 200 yd. (183 m) shutdown for cetaceans and sea turtles, 100 yd. (91 m) mitigation zone for pinnipeds (excludes haulout areas[2]). Testing: 1,000 yd. (914 m) and 500 yd. (457 m) power downs for sources that can be powered down, 200 yd. (183 m) shutdown for cetaceans, and 100 yd. (91 m) for pinnipeds (excludes haulout areas[2])
High-Frequency and Non-Hull Mounted Mid-Frequency Active Sonar[3]	AQS-22 ASW dipping sonar (MF4)	226 yd. (207 m) for one ping	20 yd. (18 m) for one ping	Not applicable	Training: 200 yd. (183 m) Testing: 200 yd. (183 m) for cetaceans and (100 yd. [91 m] for pinnipeds (excludes haulout areas[2]) from intended track of the test unit.
Explosive and Impulsive Sound					
Improved Extended Echo Ranging (IEER) Sonobuoys	Explosive sonobuoy (E4)	237 yd. (217 m)	133 yd. (122 m)	235 yd. (215 m)	Training: 600 yd. (549 m) for marine mammals, sea turtles, and concentrations of floating vegetation (under the no action alternative). n/a (under the preferred alternative)[4]. Testing: 600 yd. (549 m) for marine mammals, sea turtles, and concentrations of floating vegetation
Signal Underwater Sound (SUS) buoys Using >0.5–2.5 lb. NEW	Explosive sonobuoy >0.5–2.5 lb. NEW (E3)	178 yd. (163 m)	92 yd. (84 m)	214 yd. (196 m)	Training: 350 yd. (320 m) for marine mammals, sea turtles, and concentrations of floating vegetation. Testing: Same as Training.
Mine Countermeasure & Neutralization Activities (Positive control)	>0.5–2.5 lb. NEW (E3)	495 yd. (453 m)	145 yd. (133 m)	373 yd. (341 m)	Training: 400 yd. (366 m) for > 0.5–2.5 lb. charge for marine mammals Testing: n/a

Activity Category	Representative Source (Bin)[1]	Predicted Average Range to TTS	Predicted Average Range to PTS	Predicted Maximum Range to PTS	Recommended Mitigation Zone
Gunnery Exercises – Small- and Medium-Caliber (Surface Target)	25 mm projectile (E1)	72 yd. (66 m)	48 yd. (44 m)	73 yd. (67 m)	Training: 200 yd. (183 m) for marine mammals, sea turtles, and concentrations of floating vegetation. Testing: n/a
Gunnery Exercises – Large-Caliber (Surface Target)	5 in. projectiles (E5 at the surface[5])	210 yd. (192 m)	110 yd. (101 m)	177 yd. (162 m)	Training: 600 yd. (549 m) around target for marine mammals, sea turtles, and concentrations of floating vegetation. Testing: n/a
Missile Exercises up to 500 lb. NEW (Surface Target)	Harpoon missile (E10)	1,164 yd. (1,065 m)	502 yd. (459 m)	955 yd. (873 m)	Training: 2,000 yd. (1.8 km) for marine mammals, sea turtles, and concentrations of floating vegetation. Testing: n/a
Bombing Exercises	MK-84 2,000 lb. bomb (E12)	1,374 yd. (1,256 m)	591 yd. (540 m)	1,368 yd. (1,251 m)	Training: 2,500 yd. (2.3 km) for marine mammals, sea turtles, and concentrations of floating vegetation. Testing: n/a
Lightweight Torpedo (Explosive) Testing	MK-46 torpedo (E8)	497 yd. (454 m)	245 yd. (224 m)	465 yd. (425 m)	Training: n/a Testing: 2,100 yd. (1.9 km) for marine mammals, sea turtles, and concentrations of floating vegetation.
Heavyweight Torpedo (Explosive) Testing	MK-48 torpedo (E11)	1,012 yd. (926 m)	472 yd. (432 m)	885 yd. (809 m)	Training: n/a Testing: 2,100 yd. (1.9 km) for marine mammals, sea turtles, and concentrations of floating vegetation.
Sinking Exercises	Various sources up to MK-84 2,000 lb. bomb (E12)	1,374 yd. (1,256 m)	591 yd. (540 m)	1,368 yd. (1,251 m)	Training: 2.5 nm[6] Testing: n/a

ASW: anti-submarine warfare; in.: inches; km = kilometer; lb.: pound(s); m: meter; mm: millimeter; n/a: Not Applicable; NEW: net explosive weight; PTS: permanent threshold shift; TTS: temporary threshold shift; yd.: yard

[1] This table does not provide an inclusive list of source bins; bins presented here represent the source bin with the largest range to effects within the given activity category.

[2] The pinniped mitigation zone does not apply in the vicinity of pinnipeds hauled out on, or in the water near, man-made structures and vessels (e.g. submarines, security barriers).

[3] High-frequency and non-hull-mounted mid-frequency active sonar category includes unmanned underwater vehicle and torpedo testing activities.

[4] Although included under the No Action Alternative, training with IEER sonobuoys will no longer be conducted in the NWTT Study Area.

[5] The representative source bin E5 has different range to effects depending on the depth of activity occurrence (at the surface or at various depths).

[6] Although included under the No Action Alternative, sinking exercises will no longer be conducted in the NWTT Study Area.

3.2 Post-model analysis

The Navy Acoustic Effects Model estimates acoustic effects without taking into account any shutdown or delay of the activity when marine mammals are present and detectable within the mitigation zone; therefore, the model overestimates impacts to marine mammals within mitigation zones. The post-model analysis considers and quantifies the potential for mitigation to reduce the likelihood or risk of PTS (due to sonar and other active acoustic sources) and injuries and mortalities (due to explosives).

Two factors are considered when quantifying the effectiveness of mitigation: (1) the extent to which the type of mitigation proposed for a sound-producing activity (e.g., 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 affected by species-specific characteristics.

Mitigation Effectiveness Factor

Mitigation is considered in the quantified reduction of model-predicted effects when the mitigation zone can be fully or mostly observed prior to and during a sound-producing activity. The mitigation zones provided in Tables 3-1 and 3-2 encompass the estimated ranges to injury (including the range to mortality for explosives) for a given source. Mitigation for each activity is considered in its entirety, taking into account the different ways an event may take place (some events may have more than one scenario involving different mitigation zones, platforms, or number of Lookouts). The ability to observe the range to mortality (for explosive activities only) and the range to potential injury (for all sound-producing activities) were estimated for each training or testing event. The mitigation factors were assigned conservatively as follows:

- If the entire mitigation zone can be continuously visually observed based on the platform(s), number of Lookouts, and size of the range to effects zone, the mitigation is considered fully effective (Effectiveness = 1).
- If over half of the mitigation zone can be continuously visually observed; if there is one or more of the scenarios within the activity for which the mitigation zone cannot be continuously visually observed (but the range to effects zone can be visually observed for the majority of the scenarios); or if the mitigation zone can be continuously observed, but the activity may occur at night; the mitigation is considered mostly effective (Effectiveness = 0.5).
- If less than half of the mitigation zone can be continuously visually observed or if the mitigation zone cannot be continuously visually observed during most of the scenarios within the activity due to the type of surveillance platform(s), number of Lookouts, and size of the mitigation zone, the mitigation is not considered in the quantified reduction of model predicted acoustic effects and no reductions to mortalities or injuries due to mitigation were quantified (Effectiveness = 0). In reality, however, some protection from applied mitigation measures would be afforded even during these activities, even though it is not accounted for in the quantitative reduction of model-predicted impacts.

The Navy did not assign mitigation effectiveness factors based on detections made by other personnel that may be involved with an event in addition to Lookouts (such as range support personnel aboard a torpedo retrieval boat or support aircraft), even though in reality information about marine mammal sightings are shared amongst the units participating in the training or testing activity. Therefore, the mitigation effectiveness factors may under-estimate the likelihood that some marine mammals may be detected within the mitigation zones of some activities. Mitigation effectiveness factors are provided in Table 3-2 for activities using sonar and other active acoustic sources and in Table 3-3 for activities using explosives.

Table 3-2: Assignment of Mitigation Effectiveness Factors in the Acoustic Effects Analysis for Sonar and Other Active Acoustic Sources

Activity[1]	Mitigation Effectiveness Factor for Acoustic Analysis	Mitigation Platform[2]	Description of Mitigation[3]
Training			
Maritime Homeland Defense/Security Mine Countermeasures Integrated Exercise	1	Vessel	Mitigation zone of 200 yd. for cetaceans and 100 yd. for pinniped with 1 Lookout in vessel or helicopter.
Submarine Sonar Maintenance	0.5	Vessel	Half the scenarios would be pierside and therefore have a mitigation zone of 200(100)/500/1000 yd. with 1 Lookout or 200 yd. with 1 Lookout.
Surface Ship Sonar Maintenance	1	Vessel	Mitigation zone of 200(100)/500/1000 yd. with 2 Lookouts in vessel when underway, 1 lookout in vessel when in port.
Tracking Exercise – Surface	1	Vessel	Mitigation zone of 200(100)/500/1000 yd. with 2 Lookouts in vessel.
Tracking Exercise – Helicopter	1	Aircraft	Mitigation zone of 200(100) yd. with 1 Lookout from helicopter.
Testing			
Acoustic Test Facility	1	Vessel	Mitigation zone of 200(100)/500/1000 yd. with 1 Lookout or 200 yd. (100 yd.) with 1 Lookout. Always in inland waters where the entire activity waterspace is easily observable.
Anti-Submarine Warfare Mission Package Testing	1	Vessel	Mitigation zone of 200(100)/500/1000 yd. with 1 or 2 Lookouts depending on platform.
Cold Water Training	1	Vessel	Mitigation zone of 200(100) yd. with 1 Lookout. Approximately 75% of the time the activity takes place in inland waters where the entire activity waterspace is easily observable.
Component System Testing	1	Vessel	Mitigation zone of 200(100) yd. with 1 Lookout. Alwaystakes place in inland waters where the entire activity waterspace is easily observable.
Countermeasure Testing	1	Vessel	Mitigation zone is 200(100)/500/1000 yd. with 2 Lookouts or 200(100) yd. with 1 Lookout. Approximately 85% of the time the activity takes place in inland waters where the entire activity waterspace is easily observable.
Electromagnetic Measurement	1	Vessel	Mitigation zone of 200(100) yd. with 1 Lookout from vessel or shore. Always takes place in inland waters where the entire activity waterspace is easily observable.
Measurement System Repair & Replacement	1	Vessel	Mitigation zone of 200(100) yd. with 1 or 2 Lookouts from vessel or shore. Always takes place in inland waters where the entire activity waterspace is easily observable.
Pierside Integrated Swimmer Defense	1	Vessel	Mitigation zone of 200(100) yd. with 1 Lookout from vessel.
Pierside Sonar Testing	1	Vessel	Mitigation zone of 200(100)/500/1000 yd. with 1 Lookout or 200 yd. with 1 Lookout. Calm in-port waters good for viewing marine mammals and sea turtles.

Activity[1]	Mitigation Effectiveness Factor for Acoustic Analysis	Mitigation Platform[2]	Description of Mitigation[3]
Post-Refit Sea Trial	1	Vessel	Mitigation zone of 200(100)/500/1000 yd. with 2 Lookouts. Always takes place in inland waters where the entire activity waterspace is easily observable
Project Operations (POPS)	1	Vessel	Mitigation zone of 200(100) yd. with 2 Lookouts. Always takes place in inland waters where the entire activity waterspace is easily observable.
Proof-of-Concept Testing	1	Vessel	Mitigation zone of 200(100) yd. with 1 Lookout. Always takes place in inland waters where the entire activity waterspace is easily observable.
Surface Vessel Acoustic Measurement	1	Vessel	Mitigation zone of 200(100) yd. with 1 Lookout. Always takes place in inland waters where the entire activity waterspace is easily observable.
System, Subsystem and Component Testing – Pierside Acoustic Testing	1	Vessel	Mitigation zone of 200(100) yd. with 1 Lookout. Always takes place in inland waters where the entire activity waterspace is easily observable.
System, Subsystem and Component Testing – Performance Testing At Sea	1	Vessel	Mitigation zone of 200(100) yd. with 1 Lookout. Always takes place in inland waters where the entire activity waterspace is easily observable.
System, Subsystem and Component Testing – Development Training and Testing	1	Vessel	Mitigation zone of 200(100) yd. with 1 Lookout. Always takes place in inland waters where the entire activity waterspace is easily observable.
Target Strength Trial	1	Vessel	Mitigation zone of 200(100) yd. with 1 Lookout. Always takes place in inland waters where the entire activity waterspace is easily observable.
Torpedo (Explosive) Testing	0.5	Vessel	Mitigation zone is 200(100)/500/1000 yd. with 2 Lookouts or 200 (100) yd. with 1 Lookout. Mitigation for most sources but no mitigation for torpedo.
Torpedo Non-Explosive Testing	0.5	Vessel	Mitigation zone is 200(100)/500/1000 yd. with 2 Lookouts or 200 (100) yd. with 1 Lookout. Mitigation for most sources but no mitigation for torpedo. Approximately 65% of the time the activity takes place in inland waters where the entire activity waterspace is easily observable.
Underwater Vessel Acoustic Measurement	1	Vessel	Mitigation zone of 200(100) yd. with 1 Lookout. Always takes place in inland waters where the entire activity waterspace is easily observable.
Unmanned Underwater Vehicle Testing (all)	1	Vessel	Mitigation zone of 200(100) yd. with 1 Lookout. Always takes place in inland waters where the entire activity waterspace is easily observable.
Unmanned Vehicle Development and Payload Testing	1	Vessel	Mitigation zone of 200(100) yd. with 1 Lookout. Typically in inland waters where the entire activity waterspace is easily observable.

[1] If less than half of the mitigation zone can be continuously visually observed or if the mitigation zone cannot be continuously visually observed during most of the scenarios within the activity due to the type of surveillance platform(s), number of Lookouts, and size of the mitigation zone, mitigation is not considered in the acoustic effects analysis of that activity and the activity is not listed in this table.

[2] The activity is scored based on the ability of the individual platform to implement the mitigation.

[3] Mitigation ranges in parentheses are specific to pinnipeds.

Table 3-3: Consideration of Mitigation in Acoustic Effects Analysis for Explosives

Activity[1]	Mitigation Effectiveness Factor for Acoustic Analysis		Mitigation Platform	Description of Mitigation and Range to Effects
	Injury Zone	Mortality Zone[2]		
Training				
Bombing Exercises	0.5	1	Aircraft	Mitigation zone is 2,500 yd. (920 m) radius. Range to effects for up to bin E12 is <250 yd. radius (<500 yd. diameter) for mortality at target location with 1 Lookout from aircraft. Range to effects for up to E12 is a maximum of 1,100 yd. radius for PTS. Mitigation effectiveness for the injury zone is less than 1 but greater than 0 (assigned 0.5) due to platform speed and inability to continuously see entire 1,100 yd. range to effects zone on approach. However, >50% of range to effects zone for injury is expected to be visible.
Gunnery Exercises – Medium Caliber	0.5	0.5	Vessel	Mitigation zone is 200 yd. (183 m) for medium-caliber gunnery exercises (bin E1). Range to effects for bin E1 is <73 yd. radius (<146 yd. diameter) for mortality and injury at target location with 1 Lookout from vessel or aircraft. . Small groups not easy to see from ships at distances that may be up to 4 km away but most targets and target areas are much closer, so 0.5 was assumed reasonable.
Mine Neutralization Activities – Explosive Ordnance Disposal	0.5	1	Vessel	Mitigation zone is 400 yd. (366 m) for all charge sizes in bin E3. Activities will have 1 Lookout from vessel. Range to effects for bin E3 is within 35 yd. radius (70 yd. diameter) for mortality. Range to effects for bin E3 is a maximum of 373 yd. radius (746 yd. diameter) for PTS. Mitigation effectiveness is less than 1 but greater than 0 (assigned 0.5) for injury zone.
Sinking Exercise	0.5	1	Vessel	Mitigation zone is 2.5 nm radius for Sinking Exercises due to the use of multiple explosive sources (largest source is up to bin E12). Lookouts are located in aircraft and on vessels. Range to effects for up to bin E12 is <250 yd. radius (<500 yd. diameter) for mortality at target location. Range to effects for up to E12 is a maximum of 1,100 yd. radius for PTS. Mitigation effectiveness is less than 1 but greater than 0 (assigned 0.5) for injury zone due to the inability to continuously see entire range to effects zone. However, greater than 50 percent of range to effects zone for injury is expected to be visible.

Activity[1]	Mitigation Effectiveness Factor for Acoustic Analysis		Mitigation Platform	Description of Mitigation and Range to Effects
	Injury Zone	Mortality Zone[2]		
Testing				
Torpedo (Explosive) Testing	0.5	1	Aircraft	Mitigation zone is 2,100 yd. (1.9 km). Range to effects for up to bin E11 is <280 yd. (<560 yd. diameter) for mortality. Range to effects for up to bin E11 is <710 yd. radius (<1,420 yd. diameter) for PTS. Will have 1 lookout in aircraft if aircraft launched and 2 if surface ship launched. Long set-up time for the event means the general area will be under observation for more than an hour. Mitigation effectiveness is less than 1 but greater than 0 (assigned 0.5) for injury zone due time delay of torpedo explosion. However, greater than 50 percent of range to effects zone for injury is expected to be visible.

[1] If less than half of the mitigation zone can be continuously visually observed or if the mitigation zone cannot be visually observed during most of the scenarios within the activity due to the type of surveillance platform(s), number of Lookouts, and size of the mitigation zone, mitigation is not considered in the acoustic effects analysis of that activity and the activity is not listed in this table. For activities in which only mitigation in the mortality zone is considered in the analysis, no value is provided for the injury zone.

[2] Mortality zone is conservatively based on the range to onset mortality (i.e., 1% mortality rate) for a calf-sized animal; range to onset mortality for a median sized animal would be shorter.

Note: A-S: air-to-surface; BOMBEX: bombing exercise; GUNEX: gunnery exercise; HF: high-frequency cetacean; LF: low frequency cetacean; MF: mid-frequency cetacean; S-S: surface-to-surface.

Sightability

The ability of Navy Lookouts to detect marine mammals 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. The Navy considered what applicable data were available to numerically approximate the sightability of marine mammals and determined that the standard "detection probability" referred to as g(0) was most appropriate. The abundance of marine mammals is typically estimated using line-transect analyses (Buckland et al. 2001), in which g(0) is the probability of detecting an animal or group of animals on the transect line (the straight-line course of the survey ship or aircraft). This detection probability is derived from systematic line-transect marine mammal surveys based on species-specific estimates for vessel and aerial platforms. Estimates of g(0) are available from peer-reviewed marine mammal line-transect survey reports, generally provided through research conducted by the NMFS Science Centers.

There are two separate components of g(0): perception bias and availability bias (Marsh and Sinclair 1989). Perception bias accounts for marine mammals that are on the transect line and detectable, but were simply missed by the observer. Various factors influence the perception bias component of g(0), including species-specific characteristics (e.g., behavior and appearance, group size, and blow characteristics), viewing conditions during the survey (e.g., sea state, wind speed, wind direction, wave height, and glare), observer characteristics (e.g., experience, fatigue, and concentration), and platform characteristics (e.g., pitch, roll, speed, and height above water). To derive estimates of perception bias, typically an independent observer is present who looks for marine mammals missed by the primary observers. Mark-recapture methods are then used to estimate the probability that animals are missed by the primary observers. Availability bias accounts for animals that are missed because they are not at the surface at the time the survey platform passes by, which generally occurs more often with deep diving whales (e.g., sperm whale and beaked whale). The availability bias portion of g(0) is independent of prior marine mammal detection experience since it only reflects the probability of an animal being at the surface within the survey track and therefore available for detection.

Some g(0) values are estimates of perception bias only, some are estimates of availability bias only, and some reflect both, depending on the species and data that are currently available. The Navy used g(0) values with both perception and availability bias components if that data was available. If both components were not available for a particular species, the Navy determined that g(0) values reflecting perception bias or availability bias, but not both, still represent the best statistically-derived factor for assessing the likelihood of marine mammal detection by Navy Lookouts.

As noted above, line-transect surveys and subsequent analyses are typically used to estimate cetacean abundance. To systematically sample portions of an ocean area (such as the coastal waters off California or the east coast), marine mammal surveys are designed to uniformly cover the survey area and are conducted at a constant speed (generally 10 knots for ships and 100 knots for aircraft). Survey transect lines typically follow a pattern of straight lines or grids. Generally there are two primary observers searching for marine mammals. Each primary observer looks for marine mammals in the forward 90-degree quadrant on their side of the survey platform. Based on data collected during the survey, scientists determine the factors that affected the detection of an animal or group of animals directly along the transect line.

Visual marine mammal surveys (used to derive g(0)) are conducted during daylight[3]. Marine mammal surveys are typically scheduled for a season when weather at sea is more likely to be good, however,

[3] At night, passive acoustic data may still be collected during a marine mammal survey.

observers on marine mammal surveys will generally collect data in sea state conditions up to Beaufort 6 and do encounter rain and fog at sea which may also reduce marine mammal detections (Barlow 2006). For most species, g(0) values are based on the detection probability in conditions from Beaufort 0 to Beaufort 5, which reflects the fact that marine mammal surveys are often conducted in less than ideal conditions (Barlow 2003; Barlow and Forney 2007). The ability to detect some species (e.g., beaked whales, *Kogia* spp., and Dall's porpoise) decreases dramatically with increasing sea states, so g(0) estimates for these species are usually restricted to observations in sea state conditions of Beaufort 0 to 2 (Barlow 2003).

Navy training and testing events differ from systematic line-transect marine mammal surveys in several respects. These differences suggest the use of g(0), as a sightability factor to quantitatively adjust model-predicted effects based on mitigation, is likely to result in an underestimate of the protection afforded by the implementation of mitigation as follows:

- Mitigation zones for Navy training and testing events are significantly smaller (typically less than 1,000 yd. radius) than the area typically searched during line-transect surveys, which includes the maximum viewable distance out to the horizon.
- In some cases, Navy events can involve more than one vessel or aircraft (or both) operating in proximity to each other or otherwise covering the same general area. Additional vessels and aircraft can result in additional watch personnel observing the mitigation zone (e.g. ship shock trials). This would result in more observation platforms and observers looking at the mitigation zone than the two primary observers used in marine mammal surveys upon which g(0) is based.
- A systematic marine mammal line-transect survey is designed to sample broad areas of the ocean, and generally does not retrace the same area during a given survey. Therefore, in terms of g(0), the two primary observers have only a limited opportunity to detect marine mammals that may be present during a single pass along the trackline (i.e., deep diving species may not be present at the surface as the survey transits the area). In contrast, many Navy training and testing activities involve area-focused events (e.g., anti-submarine warfare tracking exercise), where participants are likely to remain in the same general area during an event. In other cases Navy training or testing activities are stationary (i.e., pierside sonar testing or use of dipping sonar), which allow Lookouts to focus on the same area throughout the activity. Both of these circumstances result in a longer observation period of a focused area with more opportunities for detecting marine mammals, than are offered by a systematic marine mammal line-transect survey that only passes through an area once.

Although Navy Lookouts on ships have hand-held binoculars and on some ships, pedestal mounted binoculars very similar to those used in marine mammal surveys, there are differences between the scope and purpose of marine mammal detections during research surveys along a trackline and Navy Lookouts observing the water proximate to a Navy training or testing activity to facilitate implementation of mitigation. The distinctions required careful consideration when comparing the Navy Lookouts to marine mammal surveys.[4]

- A marine mammal observer is responsible for detecting marine mammals in their quadrant of the trackline out to the limit of the available optics. Although Navy Lookouts are responsible for observing the water for safety of ships and aircraft, during specific training and testing activities, they need only detect marine mammals in the relatively small area that surrounds the mitigation zone (in most cases less than 1,000 yd. from the ship) for mitigation to be implemented.
- Navy Lookouts, personnel aboard aircraft and on watch onboard vessels at the surface will have less experience detecting marine mammals than marine mammal observers used for line-transit survey. However, Navy personnel responsible for observing the water for safety of ships and aircraft do have significant experience looking for objects (including marine mammals) on the water's surface and Lookouts are trained using the NMFS approved Marine Species Awareness Training.

Until results of the Navy's Lookout effectiveness study are available, the Navy must rely on the best available science to determine detection probabilities of marine mammals by Navy Lookouts. The factors affecting the detection of an animal or group of animals directly on the transect line may be probabilistically quantified as g(0). As a reference, a g(0) value of 1 indicates that animals on the transect line are always detected.

Table 3-4 provides detection probabilities for cetacean species based largely on g(0) values derived from shipboard and aerial surveys in the Study Area, which vary widely based on g(0) derivation factors (e.g., species, sighting platforms, group size, and sea state conditions).

[4] Barlow and Gisiner (2006) provide a description of typical marine mammal survey methods from ship and aircraft and then provide "a crude estimate" of the difference in detection of beaked whales between trained marine mammal observers and seismic survey mitigation, which is not informative with regard to Navy mitigation procedures for the following reasons. The authors note that seismic survey differs from marine mammal surveys in that, "(1) seismic surveys are also conducted at night; (2) seismic surveys are not limited to calm sea conditions; (3) mitigation observers are primarily searching with unaided eyes and 7x binoculars; and (4) typically only one or possibly two observers are searching." When Navy implements mitigation for which adjustments to modeling output were made, the four conditions Barlow and Gisiner (2006) note are not representative of Navy procedures nor necessarily a difference in marine mammal line-transect survey procedures. Navy accounts for reduced visibility (i.e. activities which occur at night, etc.) by assigning a lower value to the mitigation effectiveness factor. . On Navy ships, hand-held binoculars are always available and pedestal mounted binoculars very similar to those used in marine mammal surveys, are generally available to Navy Lookouts on board vessels over 60'. Also like marine mammal observers, Navy Lookouts are trained to use a methodical combination of unaided eye and optics as they search the surface around a vessel. The implication that marine mammal surveys only occur in "calm sea conditions" is not accurate since the vast majority of marine mammal surveys occur and data is collected in conditions up to sea states of Beaufort 5. The specific g(0) values analyzed by Barlow and Gisiner (2006) were derived from Cuvier's and *Mesoplondon* beaked whale surveys conducted in sea states of Beaufort 0-2 during daylight hours which, as noted above, is common for marine mammal surveys conducted for these particular species. However, marine mammal surveys for most species are not similarly restricted to sea states of Beaufort 0-2 and, therefore, the conclusions reached by Barlow and Gisiner (2006) regarding the effect of sea state conditions on sightability do not apply to other species. Finally, when Lookouts are present, there are always more than the "one or two personnel" described by Barlow and Gisiner (2006) observing the area ahead of a Navy vessel (additional bridge watch personnel are also observing the water around the vessel).

Table 3-4: Sightability Based on Average g(0) Values for Marine Mammal Species in the Study Area

Species	Family	Vessel Sightability	Aircraft Sightability
Baird's Beaked Whale	Ziphiidae	0.96	0.18
Blue Whale, Fin Whale, Sei Whale	Balaenopteridae	0.921	0.407
Bottlenose Dolphin	Delphinidae	0.76	0.67
California Sea Lion	Otariidae	0.299	0.299
Cuvier's Beaked Whale	Ziphidae	0.23	0.074
Dall's Porpoise	Phocoenidae	0.822	0.221
Dwarf Sperm Whale, Pygmy Sperm Whale, *Kogia* spp.	Kogiidae	0.35	0.074
Gray Whale	Eschichtiidae	0.921	0.482
Guadalupe Fur Seal	Otariidae	0.299	0.299
Harbor Porpoise	Phocoenidae	0.769	0.292
Harbor Seal	Phocidae	0.281	0.281
Humpback Whale	Balaenopteridae	0.921	0.495
Killer Whale	Delphinidae	0.921	0.95
Mesoplodon spp.	Ziphiidae	0.45	0.11
Minke Whale	Balaenopteridae	0.856	0.386
North Pacific Right Whale	Balaenidae	0.645	0.41
Northern Elephant Seal	Phocidae	0.105	0.105
Northern Fur Seal	Otariidae	0.299	0.299
Northern Right Whale Dolphin	Delphinidae	0.856	0.67
Pacific White-Sided Dolphin	Delphinidae	0.856	0.67
Risso's Dolphin, Striped Dolphin	Delphinidae	0.76	0.67
Short-Beaked Common Dolphin	Delphinidae	0.865	0.67
Short-Finned Pilot Whale	Delphinidae	0.76	0.67
Sperm Whale	Physeteridae	0.87	0.32
Steller Sea Lion	Otariidae	0.299	0.299

Notes: For species having no data, the g(0) for Cuvier's aircraft value (where g(0)=0.074) was used; or in cases where there was no value for vessels, the g(0) for aircraft was used as a conservative underestimate of sightability following the assumption that the availability bias from a slower moving vessel should result in a higher g(0). The published California Sea Lion aircraft g(0) is used for Steller Sea Lion, Guadalupe Fur Seal, and Northern Fur Seal since all are in the otariidae family and there is no g(0) data for these other species. Pinniped g(0) are not available for vessels so the aircraft value has been used as a conservative under estimate of sightability. North Atlantic right whale data (Palka 2005a; Palka 2005b) has been used for North Pacific right whale.

Sources: Barlow 2006; Barlow et al. 2006; Barlow and Forney 2007; Carretta et al. 2000; Forney and Barlow 1998; Laake et al. 1997; Palka 2005a; Palka 2005b.

The Navy recognizes that g(0) values are estimated specifically for line-transect analyses; however, g(0) is still the best statistically-derived factor for assessing the likely marine mammal detection abilities of Navy Lookouts. Based on the points summarized above, as a factor used in accounting for the implementation of mitigation, g(0) is considered to be the best available scientific basis for Navy's representation of the sightability of a marine mammal as used in this analysis.

Line transect surveys are typically performed to detect cetacean species, and data to develop sightability values for other species are limited or unavailable. Additionally, sightability data are limited for certain cetacean species. If a g(0) value was unavailable or could not be estimated for this analysis for any species, the Navy conservatively did not consider how implementation of mitigation could potentially reduce impacts to that species within this post-model analysis. The post-model analysis did not predict how implementation of mitigation could reduce acoustic impacts for sea turtles. Even though acoustic impact predictions for sea turtles were not reduced due to implementation of mitigation, sea turtles would be afforded some protection by implementation of mitigation during actual training and testing activities.

<u>Quantifying marine mammals sighted in mitigation zones</u>

To calculate the number of marine mammals that Lookouts could sight within the mitigation zones of sound-producing activities, thereby preventing a portion of model-estimated mortalities and injuries, the following equations were applied:

- Implementation of mitigation in the range to onset mortality (explosives only)

  The number of animals predicted to be sighted by Lookouts =

  Mitigation Effectiveness [factor of 0, 0.5, or 1] x

  Sightability [species-specific g(0) with a range of 0-1.0] x

  model-estimated mortalities

  The model-estimated mortalities that are calculated to be prevented by mitigation are added to the model-estimated injuries (specifically, onset slight lung injury); therefore, although some of the predicted impacts are re-categorized, the overall number of animals predicted to be affected is unchanged.

- Implementation of mitigation in the range to injury (PTS for sonar and other active acoustic sources, PTS and onset slight lung injury for explosives)

  The number of animals predicted to be sighted by Lookouts =

  Mitigation Effectiveness [factor of 0, 0.5, or 1] x

  Sightability [species-specific g(0) with a range of 0-1.0] x

  model-estimated injuries

  The model-estimated injuries that are calculated to be prevented by mitigation are added to the model-estimated non-injurious impacts (specifically, TTS); therefore, although some of the predicted impacts are re-categorized, the overall number of animals predicted to be affected is unchanged.

It is important to note that there are additional protections offered by mitigation measures that will further reduce exposures to marine mammals, but are not considered in the post-model analysis. Consistent with the Navy's impact assessment processes, the Navy considered mitigation in a conservative manner (erring on the side of overestimating the number of impacts) when quantitatively adjusting model-estimated effects to marine mammals within the applicable mitigation zones during Navy training and testing activities. Conservative considerations include the following:

- The Navy did not quantitatively account for mitigation during activities that were given a mitigation effectiveness factor of zero. A mitigation effectiveness factor of zero was given to activities where less than half of the mitigation zone can be continuously visually observed or if the mitigation zone cannot be continuously visually observed during most of the scenarios within the activity due to the type of surveillance platform(s), number of Lookouts, and size of the mitigation zone. However, some protection from applied mitigation measures would be afforded during these activities.
- The Navy only accounted for mitigation based on the required number of Lookouts, but did not account for detections that could be made by other personnel that may be involved with an event (such as range support personnel aboard a torpedo retrieval boat or support aircraft) or detections that could be made by watch personnel under implementation of Standard Operating Procedures, even though information about marine mammal sightings are shared among units participating in the training or testing activity.
- The Navy did not consider and quantify the potential for mitigation to reduce model-estimated TTS or behavioral impacts, although implementation of mitigation would likely prevent some of these impacts as well.
- Mitigation involving a power-down of sonar, cessation of sonar, or delay in use of explosives as a result of a marine mammal detection protects the observed animal and all unobserved (below the surface) animals in the vicinity. The consideration of implementation of mitigation in the post-model analysis, however, conservatively assumes that only observed animals, approximated by considering the species-specific g(0) and activity-specific mitigation effectiveness factor, would be protected by the applied mitigation (i.e., a power down, cessation of sonar, or event delay). The quantitative post-model mitigation analysis, therefore, does not capture the protection afforded to all marine mammals that may be near or within the mitigation zone.

4. MARINE MAMMAL AND SEA TURTLE AVOIDANCE OF REPEATED INTENSE SOUND EXPOSURES

- Species: all modeled species of sea turtles and marine mammals
- Activities/ Sources: Any naval activities using sonar and other active acoustic sources, or any naval activity with multiple non-concurrent underwater detonations
- Impact Zone (sonar and other active acoustic sources): Range to PTS
- Impact Zone (explosives): Range to PTS
- Flow Post-Model Acoustic Impact Analysis Process step (from Table 1-1): S-3 and E-3

4.1 BACKGROUND

4.1.1 MARINE MAMMALS

Various researchers have demonstrated that cetaceans can perceive the location and movement of a sound source (e.g., vessel, seismic source, etc.) relative to their own location and react with responsive movement away from the source, often at distances of a kilometer or more (Au and Perryman 1982; Jansen et al. 2010; Richardson et al. 1995; Tyack et al. 2011; Watkins 1986; Wursig et al. 1998).

Southall et al. (2007) synthesized data from many past behavioral studies and observations to determine the likelihood of behavioral reactions at specific sound levels. While in general, the louder the sound source the more intense the behavioral response, it was clear that the proximity of a sound source and the animal's experience, motivation, and conditioning were also critical factors influencing the response (Southall et al. 2007). After examining all of the available data, the authors felt that the derivation of thresholds for behavioral response based solely on exposure level was not supported because context of the animal at the time of sound exposure was an important factor in estimating response. Nonetheless, in some conditions, consistent avoidance reactions were noted at higher sound levels, depending on the marine mammal species or group, allowing conclusions to be drawn.

- Most low-frequency cetaceans (mysticetes) observed in studies usually avoided sound sources at levels of less than or equal to 160 dB re 1 µPa.
- Published studies of mid-frequency cetaceans analyzed include sperm whales, belugas, bottlenose dolphins, and river dolphins. These groups showed no clear tendency, but for non-impulsive sounds, captive animals tolerated levels in excess of 170 dB re 1 µPa before showing behavioral reactions, such as avoidance, erratic swimming, and attacking the test apparatus.
- High-frequency cetaceans (observed from studies with harbor porpoises) exhibited changes in respiration and avoidance behavior at levels between 90 and 140 dB re 1 µPa, with profound avoidance behavior noted for levels exceeding this.
- Phocid seals showed avoidance reactions at or below 190 dB re 1 µPa; thus, seals may actually receive levels adequate to produce TTS before avoiding the source.
- Recent studies with beaked whales have shown them to be particularly sensitive to noise, with animals during three playbacks of sound breaking off foraging dives at levels below 142 dB re 1 µPa sound pressure level, although acoustic monitoring during actual sonar exercises revealed some beaked whales continuing to forage at sound pressure levels up to 157 dB re 1 µPa (Tyack et al. 2011).

Section 3.4.3.1.6. (Behavioral Reactions) of the *Northwest Training and Testing Final EIS/OEIS* (U.S. Department of the Navy 2015) reviews additional research and observations of marine mammals' reactions to sound sources including sonar and impulsive sources.

4.1.2 Sea Turtles

Studies of sea turtle reactions to sound are limited, but they have shown that sea turtles respond to and avoid some sound exposures. A few studies examined sea turtle reactions to airguns, which produce broadband impulsive sound. O'Hara and Wilcox (1990) reported that loggerhead turtles kept in an enclosure maintained a standoff range of 98 ft. (30 m) from firing airguns. McCauley et al. (2000) estimated that the received level at which turtles avoided sound in the O'Hara and Wilcox (1990) experiment was 175–176 dB re 1 µPa root mean square. Moein-Bartol et al. (1995) investigated the use of air guns to repel juvenile loggerhead sea turtles from hopper dredges. The turtles avoided the airguns during the initial exposures (mean range of 24 m), but additional trials several days afterward did not elicit statistically significant avoidance. They concluded that this was due to either habituation or a temporary shift in the turtles' hearing capability. McCauley et al. (2000) exposed caged green and loggerhead sea turtles to an approaching-departing single air gun to gauge behavioral responses. The trials showed that above a received level of 166 dB re 1 µPa (root mean square), the turtles noticeably increased their swimming activity compared to nonoperational periods, with swimming time increasing as air gun levels increased during approach. Above 175 dB re 1 µPa (root mean square), behavior became more erratic, possibly indicating the turtles were in an agitated state (McCauley et al. 2000). The authors noted that the point at which the turtles showed the more erratic behavior and exhibited possible agitation would be expected to approximate the point at which active avoidance would occur for unrestrained turtles (McCauley et al. 2000).No studies have been performed to examine the response of sea turtles to sonar. However, based on their limited range of hearing, they may respond to sources operating below 2 kHz but are unlikely to sense higher frequency sounds.

4.2 Post-model analysis

At close ranges and high sound levels approaching those that could cause PTS, avoidance of the area immediately around the sound source is the assumed behavioral response for most cases. Because the Navy Acoustic Effects Model does not consider horizontal movement of animats, including avoidance of high-intensity sound exposures, it over-estimates the number of marine mammals and sea turtles that would be exposed to sound sources that could cause injury. In other words, the model estimates PTS impacts as though an animal would tolerate an injurious sound exposure without moving away from the sound source. Therefore, the potential for avoidance is considered in the post-model analysis.

Avoidance of high-intensity sonar exposures

Mid Frequency Cetaceans: Animal avoidance of the area immediately around the sonar or other active acoustic system would make the model-estimated PTS exposures of *mid-frequency* cetaceans unlikely. The single ping range to PTS for mid-frequency cetaceans for the most powerful sonar analyzed, the AN/SQS-53, is approximately 10 m, and the PTS range for five pings is about 20 m. The AN/SQS-53 can span as much as 270 degrees; however, an animal would need to maintain a position within a 20 m radius in front of or along the bow of the ship for over 3 minutes (given the time between five pings) to experience PTS. Additionally, odontocetes have demonstrated directional hearing, with best hearing sensitivity facing a sound source (Kastelein et al. 2005a; Mooney et al. 2008; Popov and Supin 2009). An odontocete avoiding a source would receive sounds along a less sensitive hearing axis, potentially reducing impacts.

To account for the very short range to PTS for mid-frequency cetaceans and to acknowledge the likelihood that any mid-frequency cetacean would not likely maintain close travel within the injury zone of a sonar for durations long enough to accumulate energy leading to PTS, the following post-model analysis steps were applied:

- Mid-frequency cetaceans modeled to experience PTS due to sonar and other active acoustic sources are assumed to experience TTS[5].
- The model-estimated PTS for mid-frequency cetaceans exposed to sonars and other active acoustic sources are added to the model-estimated TTS; therefore, although some of the predicted impacts are re-categorized, the overall number of animals predicted to be affected is unchanged. (Note: Although implementation of mitigation to reduce mid-frequency cetacean PTS was considered in the preceding step of the post-model quantitative analysis, consideration of animal avoidance of multiple high-intensity sonar exposures in this step mathematically overrides the previous mid-frequency cetacean PTS reductions due to mitigation, as zero mid-frequency PTS are anticipated due to during activity avoidance.)

Other marine mammals and sea turtles: Marine mammals in other functional hearing groups (i.e., low-frequency and high-frequency cetaceans; phocids [seals]; otariids [sea lions]; and mustelids [sea otters]) and sea turtles, if present but not observed by Lookouts, are assumed to leave the area near the sound source after the first few pings, thereby reducing sound exposure levels and the potential for PTS. During the first few pings of an event, or after a pause in sonar activities, if animals are caught unaware and it was not possible to implement mitigation measures (e.g., animals are at depth and not visible at the surface) it is possible they could receive enough acoustic energy to suffer PTS. Based on nominal marine mammal and sea turtle swim speeds (i.e., 3 knots) and normal operating parameters for Navy vessels (i.e., 10-15 knots), it was determined that an animal can easily avoid PTS zones within the timeframe it takes an active sound source to generate one to two pings. Example ranges to PTS are provided in Table 4-1.

Table 4-1: Approximate Ranges to PTS Onset Threshold for Each Functional Hearing Group for a Single Ping from Three of the Most Powerful Sonar Systems in the Offshore Area

Functional Hearing Group	Ranges to the Onset of PTS for One Ping (meters)[1,2]		
	Sonar Bin MF1 (e.g., SQS-53; ASW Hull Mounted Sonar)	Sonar Bin MF4 (e.g., AQS-22; ASW Dipping Sonar)	Sonar Bin MF5 (e.g., SSQ-62; ASW Sonobuoy)
Low-Frequency Cetaceans	70	10	≤ 2
Mid-Frequency Cetaceans	10	≤ 2	≤ 2
High-Frequency Cetaceans	100	20	10
Phocids (Seals)	80	10	≤ 2
Otariids (Sea Lions) Mustelids (Sea Otters)	10	≤ 2	≤ 2

ASW: anti-submarine warfare; PTS: permanent threshold shift
[1] Approximate ranges are based on spherical spreading (Transmission Loss = 20 log R, where R = range in meters).
[2] These common Navy sonar sources operate in frequency ranges above sea turtle hearing, and therefore none of these sources would affect sea turtles.

Even though marine mammals in other functional hearing groups (i.e., low-frequency and high-frequency cetaceans; phocids [seals]; otariids [sea lions]; and mustelids[sea otters]) and sea turtles could easily avoid PTS zones after one to two pings, to be conservative in this post-model analysis, animals that were model-estimated to be within the range to onset PTS for the first three to four pings

[5] All mid-frequency cetacean (delphinids and small whales, including beaked whales) PTS for sonar and other active acoustic sources are reduced to zero (and applied to TTS) due to the S-3 avoidance factor. From a mathematical perspective, consideration of mitigation for mid-frequency cetaceans exposed to sonar and other acoustic sources is irrelevant in the final result. However, because mitigation occurs second in the post-modeling assessment process, the results of mitigation are included in the calculations for mid-frequency cetaceans to provide consistency across all other species.

of an activity are assumed to not avoid onset of PTS. However, animals present beyond the range to onset PTS for the first three to four pings are assumed to avoid any additional exposures at levels that could cause PTS. The range of three to four pings accounts for differences in sonar systems and sound propagation environments.

To account for avoidance of high intensity sound exposures after the initial three to four pings, at the beginning of the activity or after a pause in sound transmission, the following post-model analysis steps were applied:

- High frequency cetaceans, low frequency cetaceans, phocids (seals), otariids (sea lions), mustelids (sea otters), and sea turtles modeled to experience PTS after the first three to four pings of an event are assumed to experience TTS.
- The model-estimated PTS for high frequency cetaceans, low frequency cetaceans, phocids (seals), otariids (sea lions), mustelids (sea otters), and sea turtles after the first three to four pings of an event are added to the model-estimated TTS; therefore, although some of the predicted impacts are re-categorized, the overall number of animals predicted to be affected is unchanged.

Avoidance of Repeated Explosive Exposures

During an activity with a series of explosions (not concurrent, i.e., not detonated concurrently in a cluster, but detonated one at a time), an animal is expected to exhibit an initial startle reaction to the first detonation followed by a behavioral response after multiple detonations. At close ranges and high sound levels approaching those that could cause PTS, avoidance of the area around the explosions is the assumed behavioral response for most cases. The ranges to PTS for each functional hearing group for a range of explosive sizes (single detonation; nominal values for deep water offshore areas) are shown in Table 4-2 through Table 4-7. Modeling for sound exposure level-based impulsive criteria assumed explosive event durations of one second. Actual durations may be less, resulting in smaller ranges to impact.

Table 4-2: Average Range to Effects from Explosions for Low-Frequency Cetaceans for Deep Water Offshore Areas

Criteria/Predicted Impact	Range to Effects (meters)			
	Bin E3 (>0.5–2.5 lb. NEW)	Bin E5 (>5-10 lb. NEW)	Bin E10 (>250-500 lb. NEW)	Bin E12 (>650-1,000 lb. NEW)
Onset Mortality	10	20	80	95
Onset Slight Lung Injury	20	40	135	165
PTS	85	170	305	485

lb.: pound; NEW: net explosive weight; PTS: permanent threshold shift

Table 4-3: Average Range to Effects from Explosions for Mid-Frequency Cetaceans for Deep Water Offshore Areas

Criteria/Predicted Impact	Range to Effects (meters)			
	Bin E3 (>0.5–2.5 lb. NEW)	Bin E5 (>5-10 lb. NEW)	Bin E10 (>250-500 lb. NEW)	Bin E12 (>650-1,000 lb. NEW)
Onset Mortality	25	45	165	200
Onset Slight Lung Injury	50	85	285	345
PTS	35	70	205	265

lb.: pound; NEW: net explosive weight; PTS: permanent threshold shift

Table 4-4: Average Range to Effects from Explosions for High-Frequency Cetaceans for Deep Water Offshore Areas

Criteria/Predicted Impact	Range to Effects (meters)			
	Bin E3 (>0.5–2.5 lb. NEW)	Bin E5 (>5-10 lb. NEW)	Bin E10 (>250-500 lb. NEW)	Bin E12 (>650-1,000 lb. NEW)
Onset Mortality	30	50	175	215
Onset Slight Lung Injury	55	90	305	370
PTS	140	375	570	855

pound; NEW: net explosive weight; PTS: permanent threshold shift

Table 4-5: Average Range to Effects from Explosions for Phocids (Seals) for Deep Water Offshore Areas

Criteria/Predicted Impact	Range to Effects (meters)			
	Bin E3 (>0.5–2.5 lb. NEW)	Bin E5 (>5-10 lb. NEW)	Bin E10 (>250-500 lb. NEW)	Bin E12 (>650-1,000 lb. NEW)
Onset Mortality	30	50	185	225
Onset Slight Lung Injury	60	100	320	385
PTS	95	180	445	680

lb.: pound; NEW: net explosive weight; PTS: permanent threshold shift

Table 4-6: Average Range to Effects from Explosions for Otariids(Sea Lions) and Mustelids (Sea Otters) for Deep Water Offshore Areas

Criteria/Predicted Impact	Range to Effects (meters)			
	Bin E3 (>0.5–2.5 lb. NEW)	Bin E5 (>5-10 lb. NEW)	Bin E10 (>250-500 lb. NEW)	Bin E12 (>650-1,000 lb. NEW)
Onset Mortality	35	65	215	260
Onset Slight Lung Injury	70	115	370	450
PTS	30	50	85	150

Table 4-7: Average Range to Effects from Explosions for Sea Turtles across Representative Offshore Acoustic Environments

Criterion/ Predicted Impact[1]	Range to Effects (meters)			
	Bin E3 (>0.5-2.5 lb. NEW)	Bin E5 (>5-10 lb. NEW)	Bin E10 (>250-500 lb. NEW)	Bin E12 (>650-1,000 lb. NEW)
Onset Mortality	26	47	164	204
Onset Slight Lung Injury	50	87	284	352
PTS	196	222	873	1,602

lb.: pound; m: meters, NEW: net explosive weight
Ranges determined using REFMS, Navy's explosive propagation model.

Animals not observed by Lookouts within the ranges to PTS at the time of the initial couple of explosions are assumed to experience PTS; however, animals that exhibit avoidance reactions beyond the initial range to PTS are assumed to move away from the expanding range to PTS effects with each additional explosion. Because the Navy Acoustic Effects Model does not account for avoidance behavior, the model-estimated effects are based on unlikely behavior – that animals would remain in the vicinity of potentially injurious sound sources. Therefore, only the initial exposures to explosive noise resulting in model-estimated PTS are expected to actually occur. To be conservative, those animals within the range to onset mortality and onset slight lung injury that are assumed to NOT be seen by Lookouts prior to the detonation [see Section 3.2 (Post-Model Analysis) for Reducing Acoustic Exposures by Implementation of Mitigation]are assumed to experience these model-estimated effects; in other words, no further post-model analysis is applied to model-estimated onset mortalities and onset slight lung injuries to account for avoidance of multiple explosive exposures. Accordingly, animals are assumed to not avoid any model-predicted gastrointestinal (GI) tract injuries (range to effect for GI tract injury is typically within the range to effect for onset slight lung injury).

For an event with a sequence of explosions which are separated temporally (e.g., by a few minutes) but detonate in the same area, the second detonation increases the zone of influence to onset-PTS by about 46 percent over the first detonation. Additional explosions, beyond the second detonation, further increase the onset-PTS zone of influence. Therefore, for events that include multiple non-current detonations, the model predicted PTS was reduced by 46 percent to account for animals avoiding the second and all subsequent detonations. This adjustment is conservative for all events that include more than two non-concurrent explosions since the ratio would be greater than 46 percent.

It should be noted that the zone of onset mortality and the zone of onset slight lung injury are not additive with multiple detonations. Any animals within these zones around a detonation location are predicted to experience these effects with the first detonation. Subsequent detonations do not increase the zones of effect for onset mortality or onset slight lung injury and do not increase the numbers of animals affected in these zones. Therefore, avoidance behavior during an explosive event is not assumed to change the predicted mortalities and slight lung injuries.

The following modifications to the model-estimates were performed in the post-model analysis for activities with multiple non-concurrent explosions listed in Table 4-8:

- All marine mammals and sea turtles modeled to receive PTS after the first explosion are assumed to move out of the range to PTS and receive TTS.

Table 4-8: Activities with Multiple Non-Concurrent Explosions

ACTIVITIES
Training
Bombing Exercises
Gunnery Exercises (Surface-to-Surface) – Ship
Mine Neutralization – Explosive Ordnance Disposal
Sinking Exercise

Note: There are no testing activities in the NWTT Study Area for which this applies.
A-S: air-to-surface; BOMBEX: bombing exercise; EOD: explosive ordnance disposal; GUNEX: gunnery exercise; MCM: mine countermeasure; S-S: surface-to-surface.

5. SUMMARY

The adjustments made to the model-estimated effects to each species at each applicable step of the post-model quantitative analysis are shown for all of the categories of training and testing activities in Table 5-1 through Table 5-5. Adjustments to mortality (explosives only), slight lung injury (explosives only), and PTS (sonar, other active acoustic sources, and explosives) are shown. All exposures which were moved out of the zone of injury were counted as TTS; the additions to the predicted TTS are not shown to simplify presentation of results. Final predicted impacts are in **BOLD**. If a step in the post-model analysis did not apply to a particular species, the species impact box is shaded. Additionally, if a step in the post-model box did not apply to impacts due to a particular training or testing activity that was analyzed separately, the species impact box is also shaded.

To illustrate the post-model quantitative analysis, the adjustments made at each post-model analysis step are shown below for several hypothetical situations. These hypothetical situations show how the steps of the post-model analysis may or may not apply depending on the species and characteristics of the sound-producing activity. The impacts in the examples below are generally higher than those predicted for any actual single event; the numbers were inflated to provide clear and easy to understand examples using whole numbers. As a reminder, the post-model analysis steps are summarized in Table 1-1, and the reader is referred to the steps in the table in these examples.

Example 1:

Source: Sonar or other active acoustic source
Activity description: not preceded by multiple vessels or helicopters, mitigation effectiveness factor of 1
Species: Baird's beaked whale (MF cetacean)

Model-estimated effects:

$TTS_{model} = 100$ $PTS_{model} = 2$

Step S-1: Is the animal a sensitive species that avoids anthropogenic activity (i.e., harbor porpoise or beaked whale)?

Yes.
If yes, is the activity preceded by multiple vessel activity or hovering helicopter?
No. Model estimates are unchanged.
$TTS_{S\text{-}1} = 100$ $PTS_{S\text{-}1} = 2$

Step S-2: Can Lookouts observe the activity-specific mitigation zone up to and during the sound-producing activity?

Yes (vessel-based Lookouts for this example). Implementation of mitigation is quantified.

The number of animals predicted to be sighted by Lookouts =

Mitigation Effectiveness [1] x Sightability [g(0)$_{beaked\ whale,\ vessel}$ = 0.96] x PTS$_{S-1}$ [2] = 1.9

Because two animals are predicted to be sighted by Lookouts within the mitigation zone, the number of predicted PTS is reduced by two and the number of TTS is increased by two.

TTS_{S-2} = 101.9 PTS_{S-2} = 0.1

Step S-3: Does the activity cause repeated sound exposures which an animal would likely avoid?

Yes.

The single ping range to PTS for an MF cetacean is short (generally less than 10 m), so all MF cetaceans estimated to experience PTS are assumed to experience TTS.

TTS_{S-3} = 102 PTS_{S-3} = 0 (Final Prediction)

Example 2:

Source: Sonar or other active acoustic source

Activity description: preceded by multiple vessels or helicopters, mitigation effectiveness factor of 0.5

Species: harbor porpoise (HF cetacean)

Model-estimated effects:

TTS_{model} = 100 PTS_{model} = 2

Step S-1: Is the animal a sensitive species that avoids anthropogenic activity (i.e., harbor porpoise or beaked whale)?

Yes.

If yes, is the activity preceded by multiple vessel activity or hovering helicopter?

Yes. Harbor porpoises modeled within the range to onset PTS are assumed to avoid the region close to the sound source prior to the beginning of sound producing activities. Harbor porpoise modeled PTS are assumed to move within the range of onset TTS.

TTS_{S-1} = 102 PTS_{S-1} = 0 (Final Prediction)

Because predicted PTS = 0, no further reductions to model-estimated impacts are possible for this activity.

Example 3:

Source: Sonar or other active acoustic source

Activity description: not preceded by multiple vessels or helicopters, mitigation effectiveness factor of 0

Species: minke whale (LF cetacean)

Model-estimated effects:

TTS_{model} = 100 PTS_{model} = 2

Step S-1: Is the animal a sensitive species that avoids anthropogenic activity (i.e., harbor porpoise or beaked whale)?

No. Model estimates are unchanged.

$TTS_{S\text{-}1}$ = 100 $PTS_{S\text{-}1}$ = 2

Step S-2: Can Lookouts observe the activity-specific mitigation zone up to and during the sound-producing activity?

No. Implementation of mitigation is not quantified (i.e., multiplying by a mitigation factor of zero predicts no animals would be observed in the mitigation zone). Model estimates are unchanged.

$TTS_{S\text{-}2}$ = 100 $PTS_{S\text{-}2}$ = 2

Step S-3: Does the activity cause repeated sound exposures which an animal would likely avoid?

Yes. Low frequency cetaceans modeled to experience PTS after the first three to four pings are assumed to experience TTS due to swimming away from the sound source and avoiding the injury zone.

$TTS_{S\text{-}3}$ = 101.9 $PTS_{S\text{-}3}$ = 0.1* (Final Prediction)

*Predicted impacts to a species are summed across all training or testing activities over a year, then rounded to an integer following general mathematic rounding rules.

<u>Example 4:</u>

<u>Source:</u> Explosive

<u>Activity description:</u> not preceded by multiple vessels or helicopters, mitigation effectiveness factors of 0 (mortality) and 0 (injury) (e.g., [A-S] MISSILEX, MISSILEX [S-S]), single or non-concurrent detonation

<u>Species:</u> Cuvier's beaked whale

Model-estimated effects:

TTS_{model} = 20 PTS_{model} = 2 SLI_{model} = 2 $Mortality_{model}$ =1

Step E-1: Is the animal a sensitive species that avoids anthropogenic activity (i.e., harbor porpoise or beaked whale)?

Yes.

If yes, is the activity preceded by multiple vessel activity or hovering helicopter?

No. Model estimates are unchanged.

$TTS_{E\text{-}1}$ = 20 $PTS_{E\text{-}1}$ = 2 $SLI_{E\text{-}1}$ = 2 $Mortality_{E\text{-}1}$ =1

Step E-2: Can Lookouts observe the activity-specific mitigation zone up to and during the sound-producing activity?

No. Model estimates are unchanged.

$TTS_{E\text{-}2}$ = 20 $PTS_{E\text{-}2}$ = 2 $SLI_{E\text{-}2}$ = 2 $Mortality_{E\text{-}2}$ =1

Step E-3: Does the activity cause repeated sound exposures which an animal would likely avoid?

No. Model estimates are unchanged.

$TTS_{E\text{-}3}$ = 20 $PTS_{E\text{-}3}$ = 2 $SLI_{E\text{-}3}$ = 2 $Mortality_{E\text{-}3}$ =1 (Final Prediction)

Example 5:

Source: Explosive
Activity description: preceded by multiple vessels or helicopters, mitigation effectiveness factor of 1 (mortality) and 1 (injury), single detonation
Species: harbor porpoise (HF cetacean)

Model-estimated effects:

TTS_{model} = 20 PTS_{model} = 2 SLI_{model} = 2 $Mortality_{model}$ =1

Step E-1: Is the animal a sensitive species that avoids anthropogenic activity (i.e., harbor porpoise or beaked whale)?

Yes.

If yes, is the activity preceded by multiple vessel activity or hovering helicopter?

Yes. Harbor porpoises modeled within the range to onset mortality are assumed to avoid the region close to the sound source prior to the beginning of sound producing activities. Harbor porpoise modeled mortalities are assumed to move within the range of onset slight lung injury.

$TTS_{E\text{-}1}$ = 20 $PTS_{E\text{-}1}$ = 2 $SLI_{E\text{-}1}$ = 3 $Mortality_{E\text{-}1}$ =0

Step E-2: Can Lookouts observe the activity-specific mitigation zone up to and during the sound-producing activity?

Yes (vessel-based Lookouts for this example). Implementation of mitigation is quantified.

No animals are predicted to be present in the mortality zone after Step E-1; therefore, mortality prediction is unchanged from Step E-1.

The number of animals predicted to be sighted by Lookouts in the injury (SLI) zone= Mitigation Effectiveness for injury [1] x Sightability [$g(0)_{harbor\ porpoise,\ vessel}$ = 0.769] x $SLI_{E\text{-}1}$ [3] = 2.3

The number of animals predicted to be sighted by Lookouts in the injury (PTS) zone=

Mitigation Effectiveness for injury [1] x Sightability [$g(0)_{harbor\ porpoise,\ vessel}$ = 0.769] x PTS_{E-1} [2] = 1.5

The animals predicted to be sighted by Lookouts within the injury zone are assumed to not be injured and are added to the animals predicted to experience TTS.

TTS_{E-2} = 23.8 PTS_{E-2} = 0.5 SLI_{E-2} = 0.7 $Mortality_{E-2}$ =0

Step E-3: Does the activity cause repeated sound exposures which an animal would likely avoid?

No. Predictions are unchanged from Step E-2.

TTS_{E-3} = 23.8 PTS_{E-3} = 0.5 SLI_{E-3} = 0.7 $Mortality_{E-3}$ =0 (Final Prediction)

Example 6:

Source: Explosive
Activity description: preceded by multiple vessels or helicopters, mitigation effectiveness factor of 1 (mortality) and 0.5 (injury), multiple detonations
Species: bottlenose dolphin (MF cetacean)

Model-estimated effects:

TTS_{model} = 20 PTS_{model} = 2 SLI_{model} = 2 $Mortality_{model}$ =1

Step E-1: Is the animal a sensitive species that avoids anthropogenic activity (i.e., harbor porpoise or beaked whale)?

No. Model estimates are unchanged.

TTS_{E-1} = 20 PTS_{E-1} = 2 SLI_{E-1} = 2 $Mortality_{E-1}$ =1

Step E-2: Can Lookouts observe the activity-specific mitigation zone up to and during the sound-producing activity?

Yes (aircraft-based Lookouts for this example). Implementation of mitigation is quantified.

The number of animals predicted to be sighted by Lookouts in the mortality zone= Mitigation Effectiveness for mortality [1] x Sightability [$g(0)_{bottlenose\ dolphin,\ aircraft}$ = 0.67] x $Mortality_{E-1}$ [1] = 0.7

The number of animals predicted to be sighted by Lookouts in the injury (SLI) zone= Mitigation Effectiveness for injury [0.5] x Sightability [$g(0)_{bottlenose\ dolphin,\ aircraft}$ = 0.67] x SLI_{E-1} [2] = 0.7

The number of animals predicted to be sighted by Lookouts in the injury (PTS) zone= Mitigation Effectiveness for injury [0.5] x Sightability [$g(0)_{bottlenose\ dolphin,\ aircraft}$ = 0.67] x PTS_{E-1} [2] = 0.7

The animals predicted to be sighted by Lookouts within the mortality zone are assumed to not be mortally injured and are added to the animals predicted to experience onset slight lung injury. The animals predicted to be sighted by Lookouts within the injury zone are assumed to not be injured and are added to the animals predicted to experience TTS.

TTS_{E-2} = 21.4 PTS_{E-2} = 1.3 SLI_{E-2} = 2 $Mortality_{E-2}$ =0.3

Step E-3: Does the activity cause repeated sound exposures which an animal would likely avoid?

Yes. Animals modeled to receive PTS after the first explosion are assumed to move out of the range to PTS and receive TTS (approximately 46 percent or more of model-predicted PTS, PTS_{model}).

TTS_{E-3} = 23.3 PTS_{E-3} = 0.3 SLI_{E-3} = 2 $Mortality_{E-3}$ =0.3 (Final Prediction)

Table 5-1: Sonar and other Active Acoustic Sources - Annual Training

Species	PTS			
	Model-Estimated	S-1 Pre-Activity Avoidance	S-2 Implementation of Mitigation	S-3 Avoidance of Repeated Exposures
Humpback whale	0		0	**0**
Blue whale	0		0	**0**
Fin whale	0		0	**0**
Sei whale	0		0	**0**
Minke whale	0		0	**0**
Gray whale	0		0	**0**
Sperm whale	0		0	**0**
Kogia (spp.)	4		3	**0**
Killer whale	0		0	**0**
Short-beaked common dolphin	0		0	**0**
Striped dolphin	0		0	**0**
Pacific white-sided dolphin	1		0	**0**
Northern right whale dolphin	0		0	**0**
Risso's dolphin	0		0	**0**
Harbor porpoise	74	74	21	**1**
Dall's porpoise	284		58	**2**
Baird's beaked whale	0	0	0	**0**
Mesoplodon beaked whales	0	0	0	**0**
Steller sea lion	0		0	**0**
California sea lion	0		0	**0**
Northern fur seal	0		0	**0**
Northern elephant seal	3		3	**0**
Harbor Seal	381		280	**6**
Leatherback Sea Turtle	0		0	**0**

Table 5-2: Sonar and Other Active Acoustic Sources - Annual Testing

Species	PTS			
	Model-Estimated	S-1 Pre-Activity Avoidance	S-2 Implementation of Mitigation	S-3 Avoidance of Repeated Exposures
Humpback whale	0		0	**0**
Blue whale	0		0	**0**
Fin whale	0		0	**0**
Sei whale	0		0	**0**
Minke whale	0		0	**0**
Gray whale	0		0	**0**
Sperm whale	0		0	**0**
Kogia (spp.)	39		26	**1**
Killer whale	1		0	**0**
Short-beaked common dolphin	6		1	**0**
Striped dolphin	0		0	**0**
Pacific white-sided dolphin	17		3	**0**
Northern right whale dolphin	7		1	**0**
Risso's dolphin	3		1	**0**
Harbor porpoise	8,155	3,865	916	**44**
Dall's porpoise	4,266		862	**43**
Cuvier's beaked whale	0	0	0	**0**
Baird's beaked whale	0	0	0	**0**
Mesoplodon beaked whales	0	0	0	**0**
Steller sea lion	0		0	**0**
California sea lion	15		11	**0**
Northern fur seal	0		0	**0**
Northern elephant seal	58		52	**2**
Harbor seal	2,382		1,713	**86**
Leatherback Sea Turtle	0		0	**0**

Table 5-3: Sonar and Other Active Acoustic Sources - Maritime Homeland Defense/Security Mine Countermeasures Integrated Exercises (Non-annual)

Species	PTS			
	Model-Estimated	S-1 Pre-Activity Avoidance	S-2 Implementation of Mitigation	S-3 Avoidance of Repeated Exposures
Humpback whale	0		0	**0**
Minke whale	0		0	**0**
Gray whale	0		0	**0**
Killer whale	0		0	**0**
Pacific white-sided dolphin	0		0	**0**
Harbor porpoise	22	0	0	**0**
Dall's porpoise	4		1	**0**
Steller sea lion	0		0	**0**
California sea lion	0		0	**0**
Northern elephant seal	0		0	**0**
Harbor seal	0		0	**0**

Table 5-4: Explosives – Annual Training

Species	PTS			Slight Lung Injury			Mortality		
	Model-Estimated	S-2 Implementation of Mitigation	S-3 Avoidance of Repeated Exposures	Model-Estimated	S-1 Pre-Activity Avoidance[1]	S-2 Implementation of Mitigation	Model-Estimated	S-1 Pre-Activity Avoidance[1]	S-2 Implementation of Mitigation
Humpback whale	0	0	**0**	0		**0**	0		**0**
Blue whale	0	0	**0**	0		**0**	0		**0**
Fin whale	0	0	**0**	0		**0**	0		**0**
Sei whale	0	0	**0**	0		**0**	0		**0**
Minke whale	0	0	**0**	0		**0**	0		**0**
Gray whale	0	0	**0**	0		**0**	0		**0**
Sperm whale	0	0	**0**	0		**0**	0		**0**
Kogia (spp.)	0	0	**0**	0		**0**	0		**0**
Killer whale	0	0	**0**	0		**0**	0		**0**
Short-beaked common dolphin	0	0	**0**	0		**0**	0		**0**
Striped dolphin	0	0	**0**	0		**0**	0		**0**
Pacific white-sided dolphin	0	0	**0**	0		**0**	0		**0**
Northern right whale dolphin	0	0	**0**	0		**0**	0		**0**
Risso's dolphin	0	0	**0**	0		**0**	0		**0**
Harbor porpoise	2	2	**0**	0	0	**0**	0	0	**0**
Dall's porpoise	4	4	**2**	1		**0**	0		**0**
Baird's beaked whale	0	0	**0**	0	0	**0**	0	0	**0**
Mesoplodon beaked whales	0	0	**0**	0	0	**0**	0	0	**0**
Steller sea lion	0	0	**0**	0		**0**	0		**0**
California sea lion	0	0	**0**	0		**0**	0		**0**
Northern fur seal	0	0	**0**	1		**0**	0		**0**
Northern elephant seal	0	0	**0**	0		**0**	0		**0**
Harbor seal	1	1	**0**	0		**0**	0		**0**
Leatherback Sea Turtle	0		**0**	0			0		

Table 5-5: Explosives – Annual Testing

	PTS			Slight Lung Injury			Mortality		
Species	**Model-Estimated**	**S-2 Implementation of Mitigation**	**S-3 Avoidance of Repeated Exposures**	**Model-Estimated**	**S-1 Pre-Activity Avoidance**	**S-2 Implementation of Mitigation**	**Model-Estimated**	**S-1 Pre-Activity Avoidance**	**S-2 Implementation of Mitigation**
Humpback whale	0	0	**0**	0		**0**	0		**0**
Blue whale	0	0	**0**	0		**0**	0		**0**
Fin whale	0	0	**0**	0		**0**	0		**0**
Sei whale	0	0	**0**	0		**0**	0		**0**
Minke whale	0	0	**0**	0		**0**	0		**0**
Sperm whale	0	0	**0**	0		**0**	0		**0**
Kogia (spp.)	0	0	**0**	0		**0**	0		**0**
Killer whale	0	0	**0**	0		**0**	0		**0**
Short-beaked common dolphin	0	0	**0**	0		**0**	0		**0**
Striped dolphin	0	0	**0**	0		**0**	0		**0**
Pacific white-sided dolphin	0	0	**0**	0		**0**	0		**0**
Northern right whale dolphin	0	0	**0**	0		**0**	0		**0**
Risso's dolphin	0	0	**0**	0		**0**	0		**0**
Harbor porpoise	0	0	**0**	0	0	**0**	0	0	**0**
Dall's porpoise	1	1	**0**	0		**0**	0		**0**
Baird's beaked whale	0	0	**0**	0	0	**0**	0	0	**0**
Mesoplodon beaked whales	0	0	**0**	0	0	**0**	0	0	**0**
Steller sea lion	0	0	**0**	0		**0**	0		**0**
California sea lion	0	0	**0**	0		**0**	0		**0**
Northern fur seal	0	0	**0**	0		**0**	0		**0**
Northern elephant seal	0	0	**0**	0		**0**	0		**0**
Leatherback Sea Turtle	0		**0**	0			0		

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