POST-MODEL QUANTITATIVE ANALYSIS OF ANIMAL AVOIDANCE BEHAVIOR AND MITIGATION EFFECTIVENESS FOR GULF OF ALASKA NAVY TRAINING ACTIVITIES SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT/ OVERSEAS ENVIRONMENTAL IMPACT STATEMENT

Technical Report
Prepared for the U.S. Pacific Fleet
May 2016

Suggested citation: U.S. Department of the Navy. 2016. Post-Model Quantitative Analysis of Animal Avoidance Behavior and Mitigation Effectiveness for Gulf of Alaska Training Activities. Technical report prepared by ManTech International Corporation for the U.S. Pacific Fleet. 34 p.

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1 INTRODUCTION

The Navy's *Gulf of Alaska Navy Training Activities Final Supplemental Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS)* (U.S. Department of the Navy 2016) 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 Gulf of Alaska Navy Training Activities Final Supplemental Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS)* (Marine Species Modeling Team 2014), available at www.GOAEIS.com, and is hereafter referred to as the modeling technical report. The second component, post-model analysis, is described in this report, and quantitatively accounts for animal avoidance behavior based on best available science and implementation of mitigation to avoid or reduce acoustic exposures during Navy training 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 activities and best available science regarding marine species, informs the comprehensive analysis of impacts to marine species presented in the *Gulf of Alaska Navy Training Activities Final Supplemental EIS/OEIS* (U.S. Department of the Navy 2016).

A basic understanding of the modeling of acoustic and explosive exposures undertaken for the *Gulf of Alaska Navy Training Activities Final Supplemental 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 [(Marine Species Modeling Team 2014]). The acoustic modeling assesses various scenarios that represent typical training activities in typical locations and seasons in the *Gulf of Alaska Navy Training Activities Final Supplemental EIS/OEIS* Study Area (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.GOAEIS.com. The predicted numbers of impacts on each species for each 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 (Tyack et al. 2011; DeRuiter et al. 2013; Manzano-Roth et al. 2013). 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 activities, regardless of how many vessels or low-flying aircraft (e.g., helicopters) are involved. The outputs of the model, therefore, present an unrealistically high estimate of acoustic impacts in close proximity to certain Navy training 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 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 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 activity grouped and summed as they are in the *Gulf of Alaska Navy Training Activities Final Supplemental EIS/OEIS*. Section 5 (Summary) shows the original model outputs and the reductions in impacts due to each step of the post-model analysis for training activities described in the Proposed Action for the *Gulf of Alaska Navy Training Activities Final Supplemental EIS/OEIS*. 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).[1]

[1] Conservative assumptions are explained in Section 3.8.3.1.6.3 (Navy Acoustic Effects Model) of the *Gulf of Alaska Navy Training Activities Supplemental EIS/OEIS* (U.S. Department of the Navy 2016). In brief, they include: (1) animats are modeled as being underwater and facing the source and, therefore, 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 impulsive-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

Is the Sound Source Sonar/Other Active Acoustic Source or Explosives?	
Sonar and Other Active Acoustic Sources	**Explosives**
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)	**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)**
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.	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.
S-2. Can Lookouts observe the activity-specific mitigation zone up to and during the sound-producing activity? (discussed in Section 3)	**E-2. Can Lookouts observe the activity-specific mitigation zone up to and during the sound-producing activity? (discussed in Section 3)**
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 Gulf of Alaska Navy Training Activities Final Supplemental EIS/OEIS). 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 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. The Mitigation Effectiveness values for activities using sonar or other active acoustic sources are provided in Table 3-2.	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 Gulf of Alaska Navy Training Activities Final Supplemental 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 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. The Mitigation Effectiveness values for explosive activities are provided in Table 3-3.
S-3. Does the activity cause repeated sound exposures which an animal would likely avoid? (discussed in Section 4)	**E-3. Does the activity cause repeated sound exposures which an animal would likely avoid? (discussed in Section 4)**
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, otariids, and phocids 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).	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 4-7.

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 steps (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 (i.e., 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, appears to avoid large vessels at about 2,995 feet (ft.). (913 meters [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 decibels (dB) (in reference to) re 1 micropascal (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. 2005a) 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 (Tyack et al. 2011; 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 (Wursig et al. 1998; Tyack et al. 2011; Pirotta et al. 2012), the post-model analysis assumed that harbor porpoises and beaked whales would avoid close interactions with certain Navy training 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 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 an offshore area representative of the Study Area:

- 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 (a mid-frequency cetacean)
- For the largest explosive for which harbor porpoise and beaked whale human activity avoidance was analyzed, bin E12 (> 650–1,000 pound [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 the net explosive weights of the majority of explosives 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 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
Carrier Strike Group Exercise	Multiple vessels and aircraft, including helicopters, present.
Sinking Exercise	Multiple vessels and aircraft, including helicopters, 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 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
Sinking Exercise	Multiple vessels and aircraft, including helicopters, present.

[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 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 and pinniped species
- Activities/Sources: Training 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 steps (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 activities are described in Chapter 5 (Standard Operating Procedures, Mitigation, and Monitoring) of the *Gulf of Alaska Navy Training Activities Final Supplemental EIS/OEIS* (U.S. Department of the Navy 2016). 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 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, PTS, out to the predicted maximum range. 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 (i.e., high frequency cetaceans). 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 Study Area.

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

Activity Category	Representative Source (Bin)[1]	Predicted (Longest) Average Range to TTS	Predicted (Longest) Average Range to PTS	Predicted Maximum Range to PTS	Recommended Mitigation Zone
Non-Impulsive Source					
Hull-Mounted Mid-Frequency Active Sonar	SQS-53 ASW hull-mounted sonar (MF1)	3,821 yd. (3.5 km) for one ping	100 yd. (91 m) for one ping	Not Applicable	6 dB power down at 1,000 yd. (914 m); 4 dB power down at 500 yd. (457 m); and shutdown at 200 yd. (183 m)
High-Frequency and Non-Hull Mounted Mid-Frequency Active Sonar	AQS-22 ASW dipping sonar (MF4)	230 yd. (210 m) for one ping	20 yd. (18 m) for one ping	Not applicable	200 yd. (183 m)
Explosive and Impulsive Source					
Signal Underwater Sound (SUS) buoys using >0.5–2.5 lb. NEW	Explosive sonobuoy (E3)	290 yd. (265 m)	113 yd. (103 m)	309 yd. (283 m)	350 yd. (320 m)
Gunnery Exercises – Small- and Medium-Caliber (Surface Target)	40 mm projectile (E2)	190 yd. (174 m)	83 yd. (76 m)	182 yd. (167 m)	200 yd. (183 m)
Gunnery Exercises – Large-Caliber (Surface Target)	5 in. projectiles (E5 at the surface[3])	453 yd. (414 m)	186 yd. (170 m)	526 yd. (481 m)	600 yd. (549 m)
Missile Exercises (Including Rockets) up to 250 lb. NEW Using a Surface Target	Maverick missile (E9)	949 yd. (868 m)	398 yd. (364 m)	699 yd. (639 m)	900 yd. (823 m)
Missile Exercises up to 500 lb. NEW (Surface Target)	Harpoon missile (E10)	1,832 yd. (1.7 km)	731 yd. (668 m)	1,883 yd. (1.7 km)	2,000 yd. (1.8 km)
Bombing Exercises	MK-84 2,000 lb. bomb (E12)	2,513 yd. (2.3 km)	991 yd. (906 m)	2,474 yd. (2.3 km)	2,500 yd. (2.3 km)[2]
Sinking Exercises	Various up to MK-84 2,000 lb. bomb (E12)	2,513 yd. (2.3 km)	991 yd. (906 m)	2,474 yd. (2.3 km)	2.5 nm[2]

[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] Recommended mitigation zones are larger than the modeled injury zones to account for multiple types of sources or charges being used.
[3] The representative source bin E5 has different range to effects depending on the depth of activity occurrence (at the surface or at various depths).
Notes: ASW = Anti-submarine Warfare, dB = decibels, km = Kilometers, lb. = Pounds, m = Meters, mm = millimeters, NEW = Net Explosive Weight, PTS = Permanent Threshold Shift, TTS = Temporary Threshold Shift, yd. = yards

3.2 POST-MODEL ANALYSIS

The Navy Acoustic Effects Model (NAEMO) 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.

3.2.1 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 Table 3-1, Table 3-2, and Table 3-3 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 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 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 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]
Carrier Strike Group Exercise	1	Vessel	6 dB power down at 1,000 yd. 4 dB power down at 500 yd. and shutdown at 200 yd.
Sinking Exercise	1	Aircraft	6 dB power down at 1,000 yd. 4 dB power down at 500 yd. and shutdown at 200 yd.

[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
	Injury Zone	Mortality Zone[2]		
Bombing Exercises	0.5	1	Aircraft	Mitigation zone is defined by a 2,500 yd. radius. Range to effects for up to bin E12 is < 260 m (284 yd.) radius for onset mortality at target location with 1 Lookout from aircraft (see tables in Section 4). Range to effects for up to E12 is a maximum of 2,474 yd. (2.3 km) radius for PTS (see Table 3-1). 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 the entire 2,474 yd. (2.3 km) radius range to effects zone on approach. However, >50 percent of range to effects zone for injury is expected to be visible.
Sinking Exercise	0.5	1	Aircraft	Mitigation zone is defined by a 2.5 nm radius for Sinking Exercises due to the use of multiple explosive sources (largest source is bin E12, which has a maximum range for PTS of 2,474 yd. (2.3 km) from the target location. Range to effects for up to bin E12 is < 260 m (284 yd.) radius for onset mortality at target location. Lookouts are located in aircraft and on vessels. Mitigation effectiveness is less than 1 but greater than 0 (assigned 0.5) for injury zone due to the inability to continuously see entire PTS range to effects zone. 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.
Notes: nm = nautical miles, yd. = yard.

3.2.2 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 were 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.[2] Marine mammal surveys are typically scheduled for a season when weather at sea is more likely to be good; however, observers on marine mammal surveys will generally collect data in sea state conditions up to Beaufort 6

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

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 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 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., Sinking Exercises). 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 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 activities are stationary (e.g., 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 activity to facilitate implementation of mitigation. The distinctions required careful consideration when comparing the Navy Lookouts to marine mammal surveys.[3]

- 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 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, which vary widely based on g(0) derivation factors (e.g., species, sighting platforms, group size, and sea state conditions).

[3] 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
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
Gray Whale	Eschichtiidae	0.921	0.482
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
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
Pacific White-Sided Dolphin	Delphinidae	0.856	0.67
Ribbon Seal	Phocidae	0.281	0.281
Sperm Whale	Physeteridae	0.87	0.32
Stejneger’s beaked whale	Ziphiidae	0.23	0.074
Steller Sea Lion	Otariidae	0.299	0.299

Notes: When there was no value available 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 g(0) for Cuvier’s beaked whale was used for Stejneger’s beaked whale given there is no data available for Stejneger’s. The published California Sea Lion aircraft g(0) is used for Steller Sea Lion and Northern Fur Seal since all are in the otariidae family and there is no g(0) data for these other species. The published Harbor Seal aircraft g(0) is used for Ribbon Seal since they are in the phocidae family and there is no g(0) data for ribbon seal. North Atlantic right whale data (Palka 2005a, b) has been used for North Pacific right whale.
Sources: Barlow 2006, Barlow and Forney 2007, Barlow et al. 2006, Carretta et al. 2000, Forney and Barlow 1998, Laake et al. 1997, Palka 2005a, b.

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 leatherback sea turtle or sea otter. Even though acoustic impact predictions for these species were not reduced due to implementation of mitigation, these species would be afforded some protection by implementation of mitigation during actual training activities.

3.2.3 Quantifying Marine Mammals Sighted in Mitigation Zones

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 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 who 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 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
- Post-Model Acoustic Impact Analysis Process steps (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 received levels of less than or equal to 160 dB re 1 µPa.
- Published studies of mid-frequency cetaceans analyzed sperm whales, belugas, bottlenose dolphins, and river dolphins (e.g., Madsen et al. 2006; Miller et al. 2009; Weir 2008; Finneran et al. 2002). These groups showed no clear tendency in responding to impulsive sounds in the field, but for non-impulsive sounds, captive animals tolerated received 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 received levels between 90 and 140 dB re 1 µPa, with profound avoidance behavior noted for levels exceeding 140 dB re 1 µPa (Southall et al. 2007).
- Phocids (true seals) showed avoidance reactions at or below a received level of 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 breaking off foraging dives during three playbacks of sound at received levels below 142 dB re 1 µPa sound pressure level. However, 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 3.8.3.1.2.6 (Behavioral Reactions) of the *Gulf of Alaska Navy Training Activities Final Supplemental EIS/OEIS* (U.S. Department of the Navy 2016) 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 (Bartol et al. 1999).

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 NAEMO 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.

4.2.1 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. 2005b; 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.[4]
- 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 [true seals], and otariids [sea lions and fur seals]), 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 cause 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. Approximate ranges to PTS are provided in Table 4-1 for a single ping transmitted from three sonar systems.

[4] 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.

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 (True Seals)	80	10	< 2
Otariids (Sea Lions and Fur Seals)	10	< 2	< 2

[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.
Notes: ASW = anti-submarine warfare; PTS = permanent threshold shift.

Even though marine mammals in other functional hearing groups 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 by the third to fourth pings of an activity are assumed to not avoid onset of PTS. However, animals located beyond the range to onset PTS by the third or fourth pings are assumed to avoid any additional exposures at levels that could cause PTS. The range of three to four pings is dependent on 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 (true seals), and otariids (sea lions and fur seals), modeled to experience PTS after the first three to four pings of an event are assumed to experience TTS.
- The model-estimated PTS exposures for high-frequency cetaceans, low-frequency cetaceans, phocids (true seals), and otariids (sea lions and fur seals) after the first three to four pings of an event are added to the model-estimated TTS exposures; therefore, although some of the predicted impacts are re-categorized, the overall number of animals predicted to be affected is unchanged.

4.2.2 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) are shown in Table 4-2 through Table 4-6. Modeling for sound exposure level-based, impulsive criteria assumed explosive event durations of 1 second. Actual durations may be less, resulting in smaller ranges to effects.

Table 4-2: Average Range to Effects from Explosions for Low-Frequency Cetaceans in the Study Area

Criteria/Predicted Impact	Range to Effects (meters)			
	Bin E4 (>2.6–5 lb. NEW)	Bin E5 (>5–10 lb. NEW)	Bin E9 (>100–250 lb. NEW)	Bin E12 (>650–1,000 lb. NEW)
Onset Mortality	10	20	65	95
Onset Slight Lung Injury	30	40	110	165
PTS	105	170	255	485

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

Table 4-3: Average Range to Effects from Explosions for Mid-Frequency Cetaceans in the Study Area

Criteria/Predicted Impact	Range to Effects (meters)			
	Bin E4 (>2.6–5 lb. NEW)	Bin E5 (>5–10 lb. NEW)	Bin E9 (>100–250 lb. NEW)	Bin E12 (>650–1,000 lb. NEW)
Onset Mortality	35	45	135	200
Onset Slight Lung Injury	80	85	235	345
PTS	40	70	170	265

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

Table 4-4: Average Range to Effects from Explosions for High-Frequency Cetaceans in the Study Area

Criteria/Predicted Impact	Range to Effects (meters)			
	Bin E4 (>2.6–5 lb. NEW)	Bin E5 (>5–10 lb. NEW)	Bin E9 (>100–250 lb. NEW)	Bin E12 (>650–1,000 lb. NEW)
Onset Mortality	40	50	145	215
Onset Slight Lung Injury	90	90	250	370
PTS	155	375	470	855

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

Table 4-5: Average Range to Effects from Explosions for Phocids (True Seals) in the Study Area

Criteria/Predicted Impact	Range to Effects (meters)			
	Bin E4 (>2.6–5 lb. NEW)	Bin E5 (>5–10 lb. NEW)	Bin E9 (>100–250 lb. NEW)	Bin E12 (>650–1,000 lb. NEW)
Onset Mortality	40	50	150	225
Onset Slight Lung Injury	100	100	265	385
PTS	115	180	340	680

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

Table 4-6: Average Range to Effects from Explosions for Otariids (Sea Lions and Fur Seals) in the Study Area

Criteria/Predicted Impact	Range to Effects (meters)			
	Bin E4 (>2.6–5 lb. NEW)	Bin E5 (>5–10 lb. NEW)	Bin E9 (>100–250 lb. NEW)	Bin E12 (>650–1,000 lb. NEW)
Onset Mortality	60	65	175	260
Onset Slight Lung Injury	115	115	307	450
PTS	25	50	50	150

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

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 NAEMO 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, of Chapter 3, 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 adjustments to the model estimated effects were performed in the post-model analysis for the activities with multiple non-concurrent explosions listed in Table 4-7:

- 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 for any subsequent explosions.

Table 4-7: Activities during the Carrier Strike Group Exercise with Multiple Non-Concurrent Explosions

ACTIVITIY
Bombing Exercise (Air-to-Surface)
Gunnery Exercise (Surface-to-Surface) – Large-Caliber
Sinking Exercise

5 SUMMARY

To illustrate the post-model quantitative analysis, the adjustments made at each post-model analysis step are shown below for six 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.

The adjustments made to the actual 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 activities in Table 5-1 and Table 5-2, which follow the hypothetical examples below.

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-1} = 100, PTS_{S-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).

If yes, 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 1.9 animals are predicted to be sighted by Lookouts within the mitigation zone, the number of predicted PTS is reduced by 1.9 and the number of TTS is increased by 1.9 (to maintain the same number of total exposures).

Model estimated effects after Step S-2:

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 a MF cetacean is short (generally less than 10 m), so, if the answer to S-3 is yes, all MF cetaceans estimated to experience PTS are assumed to experience TTS.

Model estimated effects after Step S-3:

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.

If 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.

Model estimated effects after Step S-1:

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 estimated effects after Step S-1 are unchanged.

$TTS_{S-1} = 100$, $PTS_{S-1} = 2$

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 after S-2 are unchanged.

$TTS_{S-2} = 100$, $PTS_{S-2} = 2$

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

Yes.

If yes, low-frequency cetaceans modeled to experience PTS only after the first three to four pings would experience TTS, because it is assumed that they would swim away from the sound source and avoid the injury zone. For any subsequent pings, the number of animals estimated to move out of the range to PTS is approximated as 95 percent of model-predicted PTS [i.e., PTS_{S-2}]).

95% of $PTS_{S-2} = 2 \times 0.95 = 1.9$

Model estimates after S-3:

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

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

Example 4:

Source: Explosive
Activity description: Not preceded by multiple vessels or helicopters, mitigation effectiveness factors of 0 (mortality) and 0 (injury) (e.g., [A-S MISSILEX], [S-S MISSILEX]), single or non-concurrent detonation
Species: 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-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?

No.

Model estimates are unchanged.

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

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

No.

Model estimates are unchanged.

TTS_{E-3} = 20, PTS_{E-3} = 2, SLI_{E-3} = 2, $Mortality_{E-3}$ = 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.

If 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.

Model-estimated effects after Step E-1:

TTS_{E-1} = 20, PTS_{E-1} = 2, SLI_{E-1} = 3, $Mortality_{E-1}$ = 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).

If yes, 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-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 number of animals predicted to be sighted by Lookouts within the injury zone (i.e., SLI = 2.3 and PTS = 1.5) are assumed to not be injured and are added to the animals predicted to experience TTS.

Model-estimated effects after Step E-2:

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.

Model-estimated effects after Step E-3 are unchanged:

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

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

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: Pacific white-sided 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 estimated effects after Step E-1 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).

If yes, 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 (rounded from 0.67)

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 (rounded from 0.67)

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 (rounded from 0.67)

The number of 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.

$Mortality_{E-2}$ = 1 – 0.7 = 0.3

SLI_{E-2} = 2 + 0.7 – 0.7 = 2 (0.7 mortality added to SLI)

PTS_{E-2} = 2 – 0.7 = 1.3

TTS_{E-2} = 20 + 0.7 + 0.7 = 21.4 (0.7 from SLI and 0.7 from PTS added to TTS)

Model estimated effects after Step E-2:

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.

If yes, animals modeled to receive PTS after the first explosion are assumed to move out of the range to PTS and receive TTS for any subsequent explosions. The number of animals estimated to move out of the range to PTS is approximated as 46 percent of model-predicted PTS [i.e., PTS_{E-2}]).

46% of PTS_{E-2} = 1.3 x 0.46 = 0.6

PTS_{E-3} = 1.3 – 0.6 = 0.7

TTS_{E-3} = 21.4 + 0.6 = 22.0

Model estimated effects after Step E-3:

TTS_{E-3} = 22.0, PTS_{E-3} = 0.7, SLI_{E-3} = 2, $Mortality_{E-3}$ = 0.3 (Final Prediction)

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 activities in Table 5-1 and Table 5-2. Adjustments to mortality (explosives only), slight lung injury (explosives only), and PTS (sonar and other active acoustic sources and explosives) are shown. All model-estimated effects that were moved out of the zone of injury were counted as TTS exposures; the additions to the predicted TTS exposures are not shown to simplify presentation of results.

The numbers presented in each column are the number of exposures remaining following each step in the post-modeling process. For example, in Table 5-1, there are 406 model-estimated PTS exposures of Dall's porpoise. After S-1, there are still 406 estimated exposures, because Pre-Activity Avoidance does not apply to Dall's porpoise. After S-2, there are 72 PTS exposures remaining, and after S-3 there are 3 PTS exposures remaining, which is the final total. As illustrated in the examples above, there are now 403 additional TTS exposures for Dall's porpoise (not shown in the Table 5-1).

In Table 5-1 and Table 5-2, the 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 gray.

Table 5-1: Post-Modeling Adjustments to Predicted Exposures from Sonar and other Active Acoustic Sources

Species	PTS[1]			
	Model-Estimated	S-1 Pre-Activity Avoidance	S-2 Implementation of Mitigation	S-3 Avoidance of Repeated Exposures
Baird's Beaked Whale	0	0	0	**0**
Blue Whale	1	1	0	**0**
California Sea Lion	0	0	0	**0**
Cuvier's Beaked Whale	0	0	0	**0**
Dall's Porpoise	406	406	72	**3**
Fin Whale	14	14	1	**0**
Gray Whale	0	0	0	**0**
Harbor Porpoise	0	0	0	**0**
Harbor Seal	0	0	0	**0**
Humpback Whale	1	1	0	**0**
Killer Whale	1	1	0	**0**
Minke Whale	0	0	0	**0**
North Pacific Right Whale	0	0	0	**0**
Northern Elephant Seal	1	1	1	**0**
Northern Fur Seal	0	0	0	**0**
Pacific White-Sided Dolphin	0	0	0	**0**
Sei Whale	0	0	0	**0**
Sperm Whale	0	0	0	**0**
Stejneger's beaked whale	0	0	0	**0**
Steller Sea Lion	0	0	0	**0**

[1]Values equal the number of PTS exposures after each step.

Notes: Shading indicates the step did not apply to the species. Final exposures are in bold. PTS = Permanent Threshold Shift.

Table 5-2: Post-modeling Adjustments to Exposures from Explosives

Species	PTS[1]			Slight Lung Injury[1]			Mortality[1]		
	Model-Estimated	E-2 Implementation of Mitigation	E-3 Avoidance of Repeated Exposures	Model-Estimated	E-1 Pre-Activity Avoidance	E-2 Implementation of Mitigation	Model-Estimated	E-1 Pre-Activity Avoidance	E-2 Implementation of Mitigation
Baird's Beaked Whale	0	0	**0**	0	0	**0**	0	0	**0**
Blue Whale	0	0	**0**	0	0	**0**	0	0	**0**
California Sea Lion	0	0	**0**	0	0	**0**	0	0	**0**
Cuvier's Beaked Whale	0	0	**0**	0	0	**0**	0	0	**0**
Dall’s Porpoise	4	3	1	1	1	**1**	0	0	**0**
Fin Whale	0	0	**0**	0	0	**0**	0	0	**0**
Harbor Seal	0	0	**0**	0	0	**0**	0	0	**0**
Humpback Whale	0	0	**0**	0	0	**0**	0	0	**0**
Killer Whale	0	0	**0**	0	0	**0**	0	0	**0**
Minke Whale	0	0	**0**	0	0	**0**	0	0	**0**
North Pacific Right Whale	0	0	**0**	0	0	**0**	0	0	**0**
Northern Elephant Seal	0	0	**0**	0	0	**0**	0	0	**0**
Northern Fur Seal	0	0	**0**	0	0	**0**	0	0	**0**
Pacific White-Sided Dolphin	0	0	**0**	0	0	**0**	0	0	**0**
Sei Whale	0	0	**0**	0	0	**0**	0	0	**0**
Sperm Whale	0	0	**0**	0	0	**0**	0	0	**0**
Stejneger’s beaked whale	0	0	**0**	0	0	**0**	0	0	**0**
Steller Sea Lion	0	0	**0**	0	0	**0**	0	0	**0**

[1]Values equal the number of PTS, SLI, or mortality exposures after each step.

Notes: Shading indicates the step did not apply to the species. Final exposures are in bold. PTS = Permanent Threshold Shift.

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