REQUEST FOR
LETTER OF AUTHORIZATION
FOR THE
INCIDENTAL HARASSMENT
OF MARINE MAMMALS RESULTING FROM NAVY TRAINING ACTIVITIES
CONDUCTED WITHIN THE
NORTHWEST TRAINING RANGE COMPLEX

SUBMITTED TO:

OFFICE OF PROTECTED RESOURCES

NATIONAL MARINE FISHERIES SERVICE

NATIONAL OCEANOGRAPHIC AND ATMOSPHERIC ADMINISTRATION

PREPARED BY

COMMANDER, U.S. PACIFIC FLEET

September 2008

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ACRONYMS AND ABBREVIATIONS

AAW	Anti-Air Warfare
ADC	Acoustic Device Countermeasures
ASUW	Anti-Surface Warfare
ASW	Anti-Submarine Warfare
ATOC	Acoustic Thermometry of Ocean Climate
BOMBEX	Bombing Exercise
CASS/GRAB	Comprehensive Acoustic System Simulation Gaussian Ray Bundle
CIWS	Close-in Weapons System
CV	Coefficient of Variation
dB	Decibel
DICASS	Directional Command Activated Sonobuoy System
DoN	Department of the Navy
DDG	Guided Missile Destroyer
EA/OEA	Environmental Assessment/Overseas Environmental Assessment
EER	Extended Echo Ranging
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
EL	Energy Flux Density Level (dB re $1\mu Pa^2$-s)
EMATT	Expendable Mobile Anti-Submarine Warfare Training Target
EOD	Explosive Ordnance Disposal
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FEIS	Final Environmental Impact Statement
FFG	Fast Frigate
FRTP	Fleet Readiness Training Plan
GRAB	Gaussian Ray Bundle
GUNEX	Gunnery Exercise
HARM	High-speed Anti-Radiation Missile
IEER	Improved Extended Echo Ranging
IHA	Incidental Harassment Authorization
IUCN	World Conservation Union
IWC	International Whaling Commission
kHz	Kilohertz
km	Kilometers
LOA	Letter of Authorization
m	Meter
MCM	Mine Countermeasures
MISSILEX	Missile Exercise
MMA	Multi-mission Maritime Aircraft
MMC	Marine Mammal Commision
MMHSRP	Marine Mammal Health and Stranding Response Program
MMPA	Marine Mammal Protection Act
μPa	Micropascal
MRA	Marine Resources Assessment
MSAT	Marine Species Awareness Training
NAS	Naval Air Station or National Academies of Science
NATO	North Atlantic Treaty Organization
NDE	National Defense Exemption
nm	nautical miles

nm^2	Square Nautical Miles
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
OCE	Officer-in-charge of the Exercise
OEIS	Overseas Environmental Impact Statement
ONR	Office of Naval Research
OPAREA	Operating Area
PCB	Polychlorinated biphenyl
PACNW OPAREA	Pacific Northwest Ocean Surface/Subsurface Operating Area
PTS	Permanent Threshold Shift
PUTR	Portable Undersea Tracking Range
RDT&E	Research, Development, Test, and Evaluation
RIMPAC	Rim of the Pacific
R$_{MAX}$	Impact Range
SAR	Search and Rescue
SD	Standard Deviation
SEL	Sound Exposure Level
SINKEX	Sinking Exercise
SOP	Standard Operating Procedure
SPAWAR	Navy's Space and Naval Warfare System Center
SPL	Sound Pressure Level
SSGN	Guided Missile Nuclear Submarine
SSN	Fast Attack Nuclear Submarine
SUA	Special Use Airspace
SURTASS LFA	Surveillance Towed Array Sensor System Low Frequency Active
TL	Transmission Loss
TM	Tympanic Membrane
TORPEX	Torpedo Exercise
TRACKEX	Tracking Exercise
TS	Threshold Shift
TTS	Temporary Threshold Shift
TTS2	TTS measured two minutes after exposure
UME	Unusual Mortality Events
U.S.C.	United States Code
USWEX	Undersea Warfare Exercise
UXO	Unexploded Ordnance

EXECUTIVE SUMMARY

With this submittal, the U.S. Navy (Navy) requests a five-year Letter of Authorization (LOA) for the incidental harassment of marine mammals during training events within the Northwest Training Range Complex (NWTRC) for the period October 2009 through September 2014, as permitted by the Marine Mammal Protection Act (MMPA) of 1972, as amended. The training events may expose certain marine mammals that may be present within the NWTRC to sound from hull-mounted mid- or high-frequency active tactical sonar or to pressures from explosive sources during training activities.

In order to estimate acoustic exposures from anti-submarine warfare (ASW) and mine warfare (MIW) training events occurring in the NWTRC, acoustic sources to be used were examined with regard to their operational characteristics. An analysis was conducted for NWTRC training events, modeling the potential interaction of mid-frequency active (MFA) or high-frequency active (HFA) sonar and underwater explosives, with marine mammals in the NWTRC.

The potential sonar exposures outlined in Chapter 6 represent the estimated annual maximum number of exposures to marine mammals that may result in incidental harassment of marine mammals during Navy training and testing in the NWTRC. Based on the regulatory framework established under the MMPA, the Navy has worked with the National Marine Fisheries Service (NMFS) to develop criteria and a methodology for evaluating when sound exposure might constitute incidental harassment. The MMPA defines two types of harassment; MMPA Level A (potential injury) and MMPA Level B (potential disturbance), evaluated here as follows:

- MMPA Level A: Consistent with prior actions, permanent physiological effects are considered injury, and energy flux density level (EL) is appropriate for evaluating when a sound exposure may cause a permanent physiological effect to marine mammals. EL exposures at or above the lowest threshold at which the onset of a permanent physiological effect, permanent threshold shift (PTS), may occur are used to define potential MMPA Level A harassment (215 dB re 1 μPa^2-s) for cetaceans. EL thresholds for PTS in pinnipeds are species-specific and are presented in Table ES-1 below.

- MMPA Level B from Temporary Threshold Shift (TTS): Consistent with prior actions, temporary, recoverable physiological effects are considered to potentially result in disturbance of marine mammals. Exposures below 215 dB re 1 μPa^2-s (EL) and at or above the lowest exposures at which temporary physiological effects may occur (195 dB re 1 μPa^2-s) are used to define potential MMPA Level B harassment from temporary threshold shift (TTS) for cetaceans.

- In addition to considering temporary physiological effects that may cause disturbance, this action also considers the potential for behavioral and physiological responses (e.g., stress) from exposure of marine mammals to stimuli that NMFS would classify as harassment under MMPA for military readiness activities. Based on comments received on prior Navy actions, a risk function, also referred to in this document as MMPA Level B harassment from non-TTS, is used to determine when these responses might be considered Level B harassment.

Table ES-1. Summary of the physiological effects thresholds for TTS and PTS for cetaceans and pinnipeds (SONAR Exposure).

Physiological Effects			
Animal	**Criteria**	**Threshold (re 1μPa^2-s)**	**MMPA Effect**
Cetaceans	TTS	195	Level B Harassment
	PTS	215	Level A Harassment
Pinnipeds			
Northern Elephant Seal	TTS	204	Level B Harassment
	PTS	224	Level A Harassment
Pacific Harbor Seal	TTS	183	Level B Harassment
	PTS	203	Level A Harassment
California Sea Lion	TTS	206	Level B Harassment
	PTS	226	Level A Harassment
Steller Sea Lion	TTS	206	Level B Harassment
	PTS	226	Level A Harassment
Northern Fur Seal	TTS	206	Level B Harassment
	PTS	226	Level A Harassment

The analysis used to estimate the number of marine mammals that could be exposed annually by Navy training to the portion of the MMPA Level B harassment from the risk function will overestimate the number of potential exposures. This is due to the conservative assumptions used in the modeling. Post modeling analysis is undertaken to increase the accuracy of the estimate and includes reducing acoustic footprints where they encounter land masses (land mass elimination), accounting for acoustic footprints for sonar sources that overlap to accurately sum the total area when multiple ships are operating together (correction for multiple ships), and to better account for the maximum number of individuals of a species that could potentially be exposed to sonar within the course of one day or a discreet continuous sonar event (exercise reset times and density dilution). In addition, the Navy routinely employs a number of mitigation measures, outlined in Chapter 11, which will substantially decrease the number of animals potentially exposed and affected by high levels of sonar sound, however, a reduction in the potential number of marine mammals exposed as a result of these mitigation measures is not factored into the quantification of exposures as presented below.

The acoustic modeling estimates that 129,111 marine mammals will be exposed annually to levels of mid-frequency active (MFA) or high-frequency active (HFA) sonar that will result in MMPA Level B harassment. The risk function and Navy post-modeling analysis (exercise reset times, density dilution, land mass elimination, and correction for multiple ships) estimate that of these exposures, 128,583 animals will exhibit behavioral responses that NMFS will classify as MMPA Level B harassment from non-TTS. Additionally, 528 of these annual exposures will exceed the threshold for TTS. The modeling estimates one exposure to the harbor seal, which may be exposed annually to sound levels that may exceed the threshold for permanent threshold shift (MMPA Level A harassment).

The potential explosive exposures outlined in Chapter 6 represent the maximum expected number of cetaceans and pinnipeds that could be affected from underwater explosives for mine countermeasures (MCMs), bombing exercises (BOMBEX), gunnery exercises (GUNEX), and ship sinking exercises (SINKEX). For underwater detonations, the dual criteria threshold for

potential Level B harassment is at 182 dB re 1 μPa^2-s or at 23 pounds per square inch (psi). For dual criteria, the criteria resulting in the greatest number of exposures is used. Level A thresholds are 50 percent tympanic membrane rupture, onset of slight lung injury at 205 dB or 13 psi-ms. In addition to Level A and B harassment is the onset of extensive lung injury and mortality at a threshold of 31 psi-ms. For multiple successive explosions potentially occurring during BOMBEX, SINKEX, and GUNEX (when using other than inert weapons), the acoustic criterion for a sub-TTS behavioral disturbance is used to account for behavioral effects significant enough to be judged as harassment, but occurring at lower sound energy levels that may cause TTS. The sub-TTS threshold is 177 dB re 1 μPa^2-s for multiple successive explosions.

Modeling estimates that 459 marine mammals may be exposed to pressure from explosive sources that could cause Level B harassment; 262 sub-TTS exposures and 197 exceeding 182 dB re 1μPa^2-s or 23 psi). An additional 12 are predicted to be exposed to pressures that would cause injury (Level A harassment), and no marine mammals are predicted to be exposed to pressures that could cause severe injury or mortality. However, given range clearance procedures and standard mitigation measures, the Navy believes that in actuality, there will be no injuries resulting from these activities.

As with the acoustic impacts from sonar activities, the conservative analysis used to estimate the maximum number of marine mammals that could be affected by Navy activities will overestimate the potential number of exposures and their severity. In addition, the Navy routinely employs a number of mitigation measures, outlined in Chapter 11, which the Navy believes will substantially decrease the number of animals potentially affected.

Level B harassment in the context of military readiness activities is defined by the National Defense Authorization Act (NDAA) for Fiscal Year 2004 (Public Law 108-136) as any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering to a point where such behavioral patterns are abandoned or significantly altered. This estimate of total predicted marine mammal sound exposures potentially constituting MMPA Level B harassment is presented without consideration of standard protective operating procedures. In addition, the assessment of whether temporary physiological effects or behavioral responses may cause behavioral patterns to be abandoned or significantly altered must be considered in the context of an analytical framework for active sonar. This framework acknowledges that only a subset of exposures are likely to result in MMPA Level B harassment, and that multiple exposures of the same individual will have a higher likelihood of disturbance than single exposures. All predicted acoustic exposures are presented in this analytical framework to support NMFS assessment of those exposures that may result in MMPA Level B harassment.

Based on the long history of conducting these ongoing activities using the same basic equipment in the same general areas for decades without any indications of effects to marine mammals (e.g. Hawaii and Southern California Range Complexes), the incidental harassment of marine mammals associated with the proposed Navy action will have no more than negligible impacts on marine mammal species or stocks. For species listed and protected under the Endangered Species Act (ESA), modeling estimates that seven species may be exposed to sound levels that may cause a behavioral response or reach the threshold for TTS and that may affect these species (384 exposures to sonar, and 52 exposures to explosions). The ongoing ESA Section 7 consultation will examine the anticipated responses and any associated fitness consequences for

these ESA-listed species. However, given the results of the modeling and the implementation of mitigation measures, it is unlikely that activities would adversely affect these species. Based on the widely dispersed geography of the activities and evaluation of the potential for physiological and behavioral disturbance coupled with the reduction of potential effects attributed to the mitigation measures to be executed, the interpretation of the modeling estimates that only Level B harassment is anticipated for all marine mammal species in the NWTRC. In all cases, the conclusions are that Level B harassment to a small number of marine mammals would have a negligible impact on marine mammal species or stocks. In all cases, the conclusions are that MMPA Level B harassment to a small number of marine mammals would have a negligible impact on marine mammal species or stocks.

Evidence from five beaked whale strandings, all of which have taken place outside the NWTRC, and have occurred over approximately a decade, suggests that factors of context such as the prior experience of the animals along with the presence of certain environmental conditions (e.g., multiple units using tactical sonar, steep bathymetry, constricted channels, strong surface ducts, etc.) may result in strandings, especially in beaked whales where strandings can potentially result in mortality. Although scientific uncertainty exists regarding what other factors, or combination of factors, may contribute to beaked whale strandings, the physical factors believed to contribute to the likelihood of beaked whale strandings are not present, in their aggregate, in the NWTRC.

Neither NMFS nor the Navy anticipates that marine mammal strandings or mortality will result from the use of MFA or HFA sonar during Navy exercises within the NWTRC.

1 DESCRIPTION OF ACTIVITIES

1.1 Introduction

This Chapter describes the mission activities conducted within the Northwest Training Range Complex (NWTRC) that could potentially result in harassment under the Marine Mammal Protection Act (MMPA) of 1972, as amended in 1994. The actions are U.S. Navy (Navy) activities and training events involving: mid-frequency active (MFA) tactical sonar that operates from 1 to 10 kHz; high-frequency active (HFA) sonar systems greater than 10 kHz but less than 100 kHz; military hardware, personnel, tactics, munitions, explosives, and electronic combat; and research, development, test and evaluation (RDT&E) of unmanned aerial systems (UAS). There are no active sources above 100 kHz used in the NWTRC as part of the proposed action.

The MMPA of 1972, as amended (16 United States Code [U.S.C.] Section [§] 1371[a][5]), authorizes the issuance of regulations and Letter of Authorizations (LOA) for the incidental taking of marine mammals by a specified activity for a period of not more than 5 years. The issuance occurs when the Secretary of Commerce, after notice has been published in the Federal Register and opportunity for comment has been provided, finds that such takes will have a negligible impact on the species and stocks of marine mammals and will not have an unmitigable adverse impact on their availability for subsistence uses. The National Marine Fisheries Service (NMFS) has promulgated implementing regulations under 50 Code of Federal Regulations (CFR) § 216.101–106 that provide a mechanism for allowing the incidental, but not intentional, taking of marine mammals while engaged in a specified activity.

This document has been prepared in accordance with the applicable regulations and the MMPA, as amended by the National Defense Authorization Act for Fiscal Year 2004 (Public Law 108-136). The basis of this LOA application are (1) the analysis of spatial and temporal distributions of protected marine mammals in the NWTRC (Figure 1-1), (2) a review of operational activities that have the potential to affect marine mammals, and (3) a technical risk assessment to determine the likelihood of effects from MFA and HFA.

1.2 Proposed Action

To fulfill their statutory missions, each of the Services needs combat-capable forces ready to deploy worldwide. U.S. military forces must have access to the ranges, operating areas, and airspace needed to develop and maintain skills for the conduct of military activities. Ranges, operating areas, and airspace must be sustained to support the training needed to ensure a high state of military readiness. Activities involving RDT&E for military systems are an integral part of this readiness mandate.

The Navy's mission is to organize, train, equip and maintain combat-ready naval forces capable of winning wars, deterring aggression, and maintaining freedom of the seas. Title 10, U.S. Code (U.S.C.) 5062 directs the Chief of Naval Operations (CNO) to train all naval forces for combat. The CNO meets that direction, in part, by conducting at-sea training exercises including mid-frequency active (MFA) sonar activities and ensuring naval forces have access to ranges, operating areas (OPAREAs) and airspace needed to develop and maintain skills for conducting naval opeations.
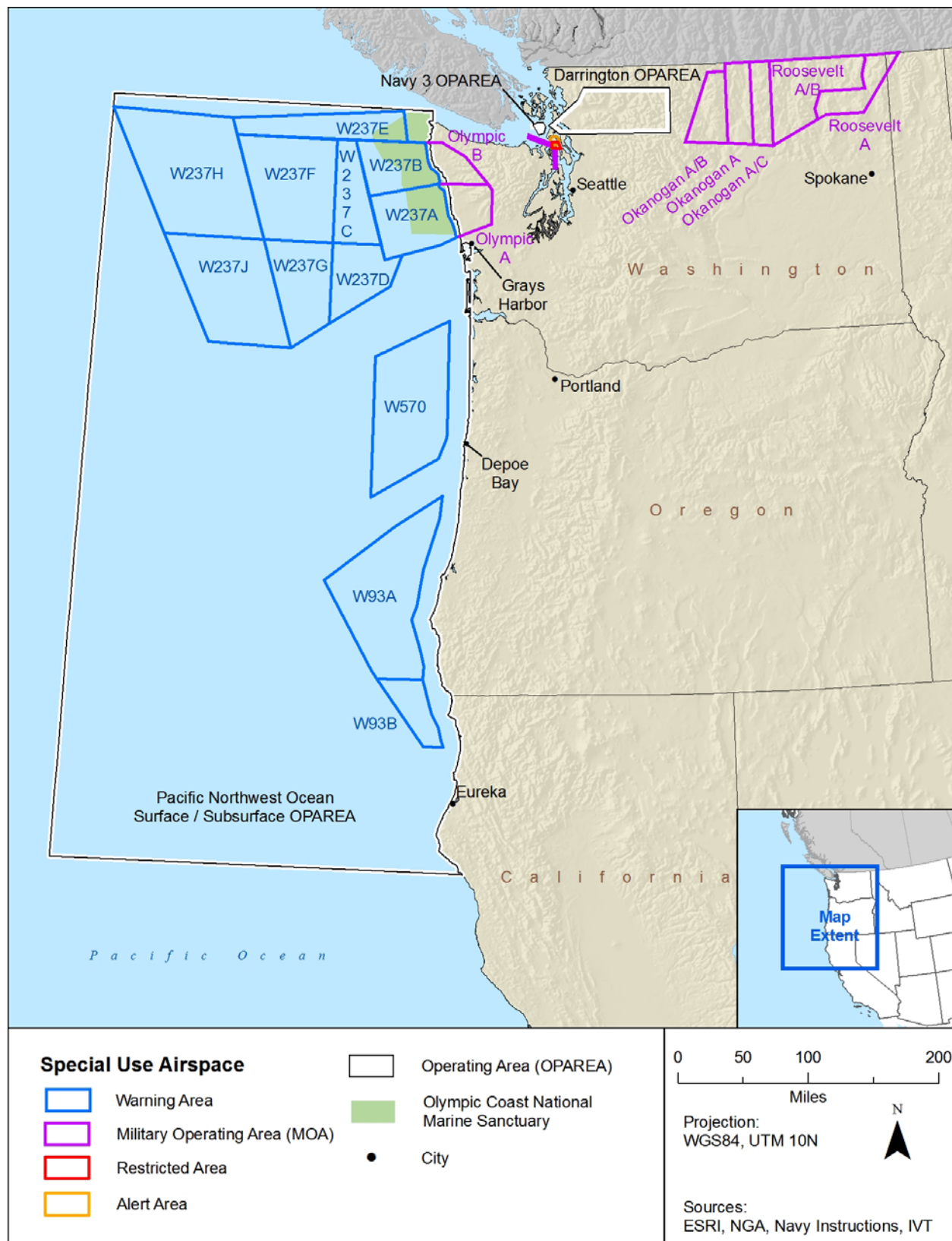
Figure 1-1: Northwest Training Range Complex

For purposes of this LOA application, the Proposed Action would support and maintain U.S. Pacific Fleet training and assessments of current capabilities, and RDT&E activities. Training and RDT&E do not include combat operations, operations in direct support of combat, or other activities conducted primarily for purposes other than training. RDT&E proposed in this action is limited to UAS activities. Undersea RDT&E in the Pacific Northwest is conducted at the Naval Sea Systems Command (NAVSEA) Keyport range and is analyzed in the NAVSEA Naval Undersea Warfare Center (NUWC) Keyport Range Extension EIS/OEIS.

The Proposed Action would result in selectively focused but critical enhancements and increases in training that are necessary if the Navy is to maintain a state of military readiness commensurate with the national defense mission. The Navy proposes to implement actions within the NWTRC to:

- Conduct training activities of the same types, and at the same levels of training intensity as currently conducted, without change in the nature or scope of military activities in the NWTRC;

- Conduct UAS RDT&E activities of the same types, and at the same levels of intensity as currently conducted, without change in the nature or scope of military activities in the NWTRC;

- Increase training activities from current levels as necessary in support of the Fleet Readiness Training Plan (FRTP);

- Accommodate force structure changes (new platforms and weapons systems); and

- Implement range enhancements associated with the NWTRC.

The NWTRC consists of airspace, surface and undersea space, and land range facilities and training areas. The activities analyzed in this LOA application include current and future proposed Navy training and UAS RDT&E activities analyzed within the NWTRC Environmental Impact Statement (EIS) study area.

The NWTRC is one of the Pacific range complexes the Navy uses for training and testing. Four ranges, including Hawaii, Southern California, Pacific Northwest and the Mariana Islands Range Complexes, support the Pacific Fleet, headquartered at Pearl Harbor. These range complexes contain some common capabilities, but each range contains distinctive individual capabilities as well. The enhancement of each range complex will be analyzed separately for potential environmental impacts. All ranges, including the NWTRC, require adequate capabilities and the flexibility to enhance and sustain Navy training and testing. This document analyzes activities that may affect marine mammals that are present in the NWTRC.

The Navy has conducted a thorough review of all continuing/ongoing training conducted in the NWTRC, in addition to those proposed training activities and UAS RDT&E events, to determine whether there is a potential for harassment of marine mammals. Sections 1.3 and 1.4 provide an overview of those training activities and events that would result in the generation of sound in the water, either through the use of sonar or from the use of live ordnance, including the detonation of explosives in the water.

For purposes of analysis, training activity data used in this LOA application are organized according to the Navy Primary Mission Areas (PMAR): (Anti-Air Warfare [AAW], Anti-Surface Warfare [ASUW], Anti-Submarine Warfare [ASW], Electronic Combat [EC], Mine Warfare

[MIW], Naval Special Warfare [NSW], Strike Warfare [STW], and Support Operations). In addition, training activity data include RDT&E events involving UAS testing. Summary descriptions of current training activities conducted in the NWTRC are provided in the following subsections.

1.3 Proposed ASW Activities

The types of ASW training conducted within the NWTRC involve the use of ships, submarines, aircraft, exercise weapons, and other training-related devices. ASW training involves the use of MFA and HFA and passive devices. A description of ASW and the sonar devices is provided below. All ASW training activities proposed in this authorization request take place in the Pacific Northwest Ocean Surface/Subsurface Operating Area (PACNW OPAREA) (see Figure 1-1).

1.3.1 ASW Training Activities

ASW involves helicopter and sea control aircraft, ships, and submarines, operating alone or in combination, to locate, track, and neutralize submarines. Controlling the undersea battlespace is a unique naval capability and a vital aspect of sea control. Undersea battlespace dominance requires proficiency in ASW. Every deploying strike group and individual surface combatant must possess this capability.

Various types of active and passive sonars are used by the Navy to determine water depth, locate mines, and identify, track, and target submarines. Passive sonar "listens" for sound waves by using underwater microphones, called hydrophones, which receive, amplify and process underwater sounds. No sound is introduced into the water when using passive sonar. Passive sonar can indicate the presence, character and movement of submarines. However, passive sonar provides only a bearing (direction) to a sound-emitting source; it does not provide an accurate range (distance) to the source. Also, passive sonar relies on the underwater target itself to provide sufficient sound to be detected by hydrophones. Active sonar is needed to locate quiet objects (such as mines or diesel-electric submarines operating in electric mode) and to establish both bearing and range to the detected contact.

Active sonar transmits pulses of sound that travel through the water, reflect off objects and return to a receiver. By knowing the speed of sound in water and the time taken for the sound wave to travel to the object and back, active sonar systems can quickly calculate direction and distance from the sonar platform to the underwater object. There are three types of active sonar: low frequency, mid-frequency, and high-frequency.

Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar operates below 1 kHz and is designed to detect extremely quiet diesel-electric submarines at ranges far beyond the capabilities of MFA sonars. There are currently only two ships in use by the Navy that are equipped with LFA sonar; both are ocean surveillance vessels operated by Military Sealift Command (MSC). LFA sonar is not presently utilized in the NWTRC, and is not part of the Proposed Action.

Mid-frequency active (MFA) sonar, as defined in this LOA application, operates between 1 and 10 kHz, with detection ranges up to 10 nm (19 km). Because of this detection ranging capability, MFA sonar is the Navy's primary tool for conducting ASW. Many ASW experiments and exercises have demonstrated that this improved capability for long range detection of adversary

submarines before they are able to conduct an attack is essential to U.S. ship survivability. Today, ASW is the Navy's #1 war-fighting priority. Navies across the world utilize modern, quiet, diesel-electric submarines which pose the primary threat to the U.S. Navy's ability to perform a number of critically necessary missions. Extensive training is necessary of if Sailors, ships, and strike groups are to gain proficiency in using MFAS. If a strike group does not demonstrate MFAS proficiency, it cannot be certified as combat ready.

High-frequency active (HFA) sonar, as defined in this LOA application, operates at frequencies greater than 10 kilohertz (kHz). At higher acoustic frequencies, sound rapidly dissipates in the ocean environment, resulting in short detection ranges, typically less than five nm (9 km). High-frequency sonar is used primarily for determining water depth, hunting mines and guiding torpedoes.

ASW sonar systems are deployed from certain classes of surface ships, submarines, and fixed-wing maritime patrol aircraft (MPA). Maritime patrol aircraft is a category of fixed-wing aircraft that includes the current P-3C Orion, and the future P-8 Poseidon multimission maritime aircraft. No ASW helicopters train in the NWTRC. The surface ships used are typically equipped with hull-mounted sonars (passive and active) for the detection of submarines. Fixed-wing MPA are used to deploy both active and passive sonobuoys to assist in locating and tracking submarines or ASW targets during the exercise. Submarines are equipped with passive sonar sensors used to locate and prosecute other submarines and/or surface ships during the exercise. The types of active tactical sonar sources employed during ASW sonar training exercises are identified in Table 1-1.

Table 1-1: ASW and MIW Active Sonar Systems and Platforms in the NWTRC

System	Frequency	Associated Platform/Use
AN/SQS-53	MF	DDG and CG hull-mounted sonar
AN/SQS-56	MF	FFG hull-mounted sonar
AN/BQS-15	HF	Submarine mine detection sonar
Range Uplink Transducer	MF / HF	Portable Undersea Tracking Range
Range Tracking Pingers	HF	Ships, submarines, ASW targets
MK-48 Torpedo	HF	Submarine fired exercise torpedo (used during SINKEX)
Tonal sonobuoy (DICASS) (AN/SSQ-62)	MF	MPA deployed
CG – Guided Missile Cruiser; DDG – Guided Missile Destroyer; DICASS – Directional Command-Activated Sonobuoy System; FFG – Fast Frigate; HF – High-Frequency; MF – Mid-Frequency.		

ASW Tracking Exercise (TRACKEX) trains aircraft, ship, and submarine crews in tactics, techniques, and procedures for search, detection, localization, and tracking of submarines with the goal of determining a firing solution that could be used to launch a torpedo and destroy the submarine. ASW Tracking Exercises occur during both day and night. A typical unit-level exercise, involves one (1) ASW unit (aircraft, ship, or submarine) versus one (1) target; either a MK-39 Expendable Mobile ASW Training Target (EMATT), or a live submarine. The target may be non-evading while operating on a specified track or fully evasive. Participating units use active and passive sensors, including hull-mounted sonar, towed arrays, and sonobuoys for tracking. If the exercise continues into the firing of a practice torpedo it is termed a Torpedo Exercise (TORPEX). The ASW TORPEX usually starts as a TRACKEX to achieve the firing solution. No torpedoes are fired during ASW training conducted in the NWTRC.

1.3.1.1 ASW TRACKEX (Maritime Patrol Aircraft)

During an ASW TRACKEX (MPA), a typical scenario would involve a single MPA dropping sonobuoys, from an altitude below 3,000 ft (914 m) MSL, and sometimes as low as 400 ft (122 m), into specific patterns designed for both the anticipated threat submarine and the specific water conditions. These patterns vary in size and coverage area based on the threat and water conditions. Typically, passive sonobuoys will be used first, so the threat submarine is not alerted. Active buoys will be used as required either to locate extremely quiet submarines, or to further localize and track submarines previously detected by passive buoys. A TRACKEX (MPA) usually takes two to four hours.

The P-8 Multi-mission Maritime Aircraft (MMA), a modified Boeing 737, is the Navy's replacement for the aging P-3 Orion aircraft. The MMA is a long-range aircraft that is capable of broad-area, maritime and littoral activities. Naval Air Station Whidbey Island (NASWI), the current home base for P-3 aircraft, is being analyzed as a potential homebasing location for this aircraft in the ongoing MMA Homebasing EIS. Currently, the MMA preferred alternative in the Homebasing EIS is 4 P-8 squadrons to replace 4 P-3 squadrons at NASWI. As P-8 live training is expected to be supplemented with virtual training to a greater degree than P-3 training, P-8 training activities in the NWTRC are likely to be less numerous than those currently conducted by P-3 aircraft crews. P-3 replacement is expected to begin by 2013. None of the potential marine mammal impacts associated with the P-3 aircraft are expected to differ as a result of the P-3 being replaced with the MMA.

1.3.1.2 ASW TRACKEX (Extended Echo Ranging/Improved Extended Echo Ranging)

This activity is an at-sea flying event, typically conducted below 3,000 ft (914 m) MSL, that is designed to train P-3 crews in the deployment and use of the Extended Echo Ranging (EER) /Improved Extended Echo Ranging (IEER) sonobuoy systems. These systems use the SSQ-110A as the signal source and the SSQ-77 as the receiver buoy. The signal source is a small explosive charge that detonates underwater. The SSQ-110A sonobuoy has two charges, each being individually detonated during the exercise. This activity typically lasts six hours, with one hour for buoy pattern deployment and five hours for active search. Between 12 and 20 SSQ-110A source sonobuoys and approximately 20 SSQ-77 passive sonobuoys are used in a typical exercise.

1.3.1.3 ASW TRACKEX (Surface Ship)

In the PACNW OPAREA, locally based surface ships do not routinely conduct ASW Tracking exercises. However, mid-frequency active (MFA) sonar is used during ship transits through the OPAREA. In a typical year, 24 Guided Missile Destroyer (DDG) ship transits and 36 Fast Frigate (FFG) transits will take place, with 1.5 hours of active sonar use during each transit. All surface ship MFA sonar use is documented in this training activity description.

1.3.1.4 ASW TRACKEX (Submarine)

ASW TRACKEX is a primary training exercise for locally based submarines. Training is conducted within the NWTRC and involves aircraft approximately 30% of the time. Training events in which aircraft are used typically last 8 to 12 hours. During these activities submarines use passive sonar sensors to search, detect, classify, localize and track the threat submarine with the goal of developing a firing solution that could be used to launch a torpedo and destroy the

threat submarine. However, no torpedoes are fired during this training activity. All submarine ASW TRACKEX conducted in the NWTRC is passive only, therefore these activities are not carried forward for any further analysis of effects. All aircraft ASW is analyzed under ASW TRACKEX (MPA).

1.3.2 Active Acoustic Sources

Modern sonar technology has developed a multitude of sonar sensor and processing systems. In concept, the simplest active sonars emit omni-directional pulses ("pings") and time the arrival of the reflected echoes from the target object to determine range. More sophisticated active sonar emits an omni-directional ping and then rapidly scans a steered receiving beam to provide directional, as well as range, information. More advanced sonars transmit multiple preformed beams, listening to echoes from several directions simultaneously and providing efficient detection of both direction and range.

The tactical military sonars to be deployed during training in the NWTRC are designed to detect submarines. This task requires the use of the sonar mid-frequency range of 1 to 10 kHz predominantly. HFA sources in the range above 10 kHz are used during training in the NWTRC and include fathometers, range tracking pingers, range uplink transmitters, and torpedoes. These systems are not expected to represent significant sources of sound exposure given the generally lower source levels and characteristic rapid attenuation of high frequency sound waves underwater; however, further analysis of these sources is continuing. If further analysis determines there may be effects from these sources, supplemental information will be provided. Accordingly, the only HFA source modeled for potential exposures to marine mammals in the NWTRC area is associated with the MK-48 torpedo.

The types of tactical acoustic sources that would be used in training events are discussed in the following paragraphs.

- **Surface Ship Sonars.** A variety of surface ships participate in training events. Of the ships that operate in the NWTRC, only two classes employ MFA sonar; the Fast Frigate (FFG) and the Guided Missile Destroyer (DDG). These two classes of ship are equipped with active as well as passive tactical sonars for mine avoidance and submarine detection and tracking. DDG class ships are equipped with the SQS-53C sonar system, with a nominal source level of 235 decibels (dB) re 1 µPa @ 1 m. The FFG class ship uses the SQS-56 sonar system, with a nominal source level of 225 decibels (dB) re 1 µPa @ 1 m. Sonar ping transmission durations were modeled as lasting 1 second per ping and omni-directional, which is a conservative assumption that will overestimate potential effects. Actual ping durations will be less than 1 second. The SQS-53 hull-mounted sonar transmits at a center frequency of 3.5 kHz. The SQS-56 transmits at a center frequency of 7.5 kHz. Details concerning the tactical use of specific frequencies and the repetition rate for the sonar pings is classified but was modeled based on the required tactical training setting.

- **Submarine Sonars.** Submarine active sonars are not used in the NWTRC and are not carried forward for any further analysis of effects. However, the AN/BQS-15 sonar would be used for mine detection training. The AN/BQS-15, installed on guided missile nuclear submarines (SSGN) and fast attack nuclear submarines (SSN), uses high frequency (> 10 kHz) active sonar to locate mine shapes. A total of seven mine avoidance

exercises would take place annually in the NWTRC. Each exercise would have a six hour duration.

- **Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA).** SURTASS LFA use is not part of the proposed action in the NWTRC and was not modeled as part of the NWTRC DEIS or this LOA application. Therefore, SURTASS LFA is not carried forward for any further analysis of effects.

- **Aircraft Sonar Systems.** Sonobuoys are the only aircraft sonar systems that would operate in the NWTRC. Sonobuoys, deployed by maritime patrol aircraft, are expendable devices used for the detection of submarines. Most sonobuoys are passive, but some can generate active acoustic signals, as well as listen passively. During ASW training, these systems' active modes are used for localization of contacts and are not typically used in primary search capacity. The AN/SSQ-62 Directional Command Activated Sonobuoy System (DICASS) is the only MFA sonobuoy used in the NWTRC. Because no ASW helicopters train in the NWTRC, no dipping sonar system is carried forward for any further analysis of effects.

- **Extended Echo Ranging and Improved Extended Echo Ranging (EER/IEER) Systems.** EER/IEER are airborne ASW systems used in conducting "large area" searches for submarines. These systems are made up of airborne avionics ASW acoustic processing and sonobuoy types that are deployed in pairs. The EER/IEER System's active sonobuoy component, the AN/SSQ-110A Sonobuoy, generates an explosive sound impulse and a passive sonobuoy would "listen" for the return echo that has been bounced off the surface of a submarine. These sonobuoys are designed to provide underwater acoustic data necessary for naval aircrews to quickly and accurately detect submerged submarines. The sonobuoy pairs are dropped from a maritime patrol aircraft into the ocean in a predetermined pattern with a few buoys covering a very large area. The AN/SSQ-110A Sonobuoy Series is an expendable and commandable sonobuoy. Upon command from the aircraft, the explosive charge would detonate, creating the sound impulse. Within the sonobuoy pattern, only one detonation is commanded at a time. Twelve to twenty SSQ-110A source sonobuoys are used in a typical exercise. Both charges of each sonobuoy would be detonated during the course of the training, either tactically to locate the submarine, or when the sonobuoys are commanded to scuttle at the conclusion of the exercise.

- **Advanced Extended Echo Ranging (AEER) system.** The proposed AEER system is operationally similar to the existing EER/IEER system. The AEER system will use the same ADAR sonobuoy as the acoustic receiver and will be used for a large area ASW search capability in both shallow and deep water. However, instead of using an explosive AN/SQS-110A as an impulsive source for the active acoustic wave, the AEER system will use a battery powered (electronic) source for the AN/SSQ 125 sonobuoy. The output and operational parameters for the AN/SSQ-125 sonobuoy (source levels, frequency, wave forms, etc.) are classified, however, this sonobuoy is intended to replace the EER/IEER's use of explosives and is scheduled to enter the fleet in 2011. Acoustic impact analysis for the AN/SSQ-125 in this document assumes a similar per-buoy effect as that modeled for the DICASS sonobuoy. For purposes of analysis, replacement of the EER/IEER system by the AEER system will be assumed to occur at 25% per year as

follows: 2011 - 25% replacement; 2012 - 50% replacement; 2013 - 75% replacement; 2014 - 100% replacement with no further use of the EER/IEER system beginning in 2015 and beyond.

- **Torpedoes.** Torpedoes are the primary ASW weapon used by surface ships, aircraft, and submarines. The guidance systems of these weapons can be autonomous or electronically controlled from the launching platform through an attached wire. The autonomous guidance systems are acoustically based. They operate either passively, exploiting the emitted sound energy by the target, or actively, ensonifying the target and using the received echoes for guidance. The MK-48 submarine-launched torpedo, used in its anti-surface ship mode, was modeled for active sonar transmissions in Sinking Exercises conducted within the NWTRC.

- **Portable Undersea Tracking Range.** The Portable Undersea Tracking Range (PUTR) has been developed to support ASW training in areas where the ocean depth is between 300 ft and 12,000 ft and at least 3 nm from land. This proposed project would temporarily instrument 25-square-mile or smaller areas on the seafloor, and would provide high fidelity feedback and scoring of crew performance during ASW training activities. When training is complete, the PUTR equipment would be recovered. All of the potential PUTR areas have been used for ASW training for decades.

  No on-shore construction would take place. Seven electronics packages, each approximately 3 ft long by 2 ft in diameter, would be temporarily installed on the seafloor by a range boat, in water depths greater than 600 ft. The anchors used to keep the electronics packages on the seafloor would be either concrete or sand bags, approximately 1.5 ft-by-1.5 ft and 300 pounds. Each package consists of a hydrophone that receives pinger signals, and a transducer that sends an acoustic "uplink" of locating data to the range boat. The uplink signal is transmitted at 8.8 kilohertz (kHz), 17 kHz, or 40 kHz, at a source level of 190 decibels (dB). The Portable Undersea Tracking Range system also incorporates an underwater voice capability that transmits at 8-11 kHz and a source level of 190 dB. Each of these packages is powered by a D cell alkaline battery. After the end of the battery life, the electronic packages would be recovered and the anchors would remain on the seafloor. The Navy proposes to deploy this system for 3 months of the year (approximately June – August), and to conduct TRACKEX activities for 10 days per month in an area beyond 3 nm from shore. During each of the 30 days of annual operation, the PUTR would be in use for 5 hours each day. No additional ASW activity is proposed as a result of PUTR use. Operation of this range requires that underwater participants transmit their locations via pingers (see "Range Tracking Pingers" below).

- **Range Tracking Pingers.** MK-84 range tracking pingers would be used on ships, submarines, and ASW targets when ASW TRACKEX training is conducted on the PUTR. The MK-84 pinger generates a 12.93 kHz sine wave in pulses with a maximum duty cycle of 30 milliseconds (3% duty cycle) and has a design power of 194 dB re 1 micro-Pascal at 1 meter. Although the specific exercise, and number and type of participants will determine the number of pingers in use at any time, a minimum of one and amaximum of three pingers would be used for each ASW training activity. On average, two pingers would be in use for 3 hours each during PUTR operational days.

1.4 Proposed Non-ASW Activities

1.4.1 Anti-Air Warfare Training

Anti-Air Warfare (AAW) is the PMAR that addresses combat operations training by air and surface forces against hostile aircraft.

1.4.1.1 Air Combat Maneuvers

Air Combat Maneuvers (ACM) involve aircraft engaged in high altitude flight activities in which no ordnance is released and no potential impacts to marine mammals exists. Therefore, ACM activities are not carried forward for any further analysis of effects.

1.4.1.2 Air-to-Air Missile Exercise

During an Air-to-Air Missile Exercise (AAMEX), aircraft attack a simulated threat target aircraft with air-to-air missiles with the goal of destroying the target.

A typical Basic Phase (Unit Level Training) Scenario would involve a flight of two aircraft operating between 15,000 to 25,000 ft (4,572 to 7,620 m) and at a speed of about 450 kts that approach a target from several miles away and, when within missile range, launch their missiles against the target. Approximately half of the missiles have live warheads and about half have an inert telemetry head package. The live warheads are designed to explode in the air. None of the missiles fired during this activity are recovered.

The target is either a Tactical Air-Launched Decoy (TALD) or a LUU-2B/B illumination paraflare. Both the TALDs and the paraflares are expended. These exercises last about one hour, and are conducted in a warning area at sea outside of 12 nm (22 km) and well above 3,000 ft (914 m) MSL.

1.4.1.3 Surface-to-Air Gunnery Exercise

During a Surface-to-Air Gunnery Exercise (GUNEX S-A), a ship's gun crews engage threat aircraft or missile targets with their guns with the goal of disabling or destroying the threat. A typical scenario involves a threat aircraft or anti-ship missile simulated by an aircraft-towed target approaching the ship below 10,000 ft (3,048 m), at a speed between 250 and 500 kts. A DDG will engage the target with 5-inch guns, and an FFG will use 76 mm main battery guns. This is a defensive exercise where approximately six rounds of 5-inch inert ammunition and 12 rounds of 76 mm inert ammunition are fired at the target. The ship will maneuver as necessary and will typically operate at 10 to 12 kts or less during the exercise. The exercise lasts about two hours, which normally includes several non-firing tracking runs followed by one or more the firing runs. The target must maintain an altitude above 500 ft (152 m) MSL for safety reasons and is not destroyed during the exercise.

A typical scenario involving a DDG or FFG with 20 mm Close-in Weapon System (CIWS) is similar, except the ships involved engage the simulated threat aircraft or missile with the CIWS. Approximately 16,000 rounds of 20 mm are expended annually during CIWS S-A GUNEX activities. Some of the 20 mm CIWS rounds may contain depleted uranium (DU).

1.4.1.4 Surface-to-Air Missile Exercise

During a Surface-to-Air Missile Exercise (SAMEX), surface ships engage threat missiles and aircraft with surface-to-air missiles (SAMs) with the goal of disabling or destroying the threat.

One live or telemetered-inert-missile is expended against a target towed by an aircraft after two or three tracking runs. The exercise lasts about two hours. A BQM-74 aerial target drone, sometimes augmented with a Target Drone Unit (TDU), is used as an alternate target for this exercise. The BQM target is a subscale, subsonic, remote controlled ground or air launched target. A parachute deploys at the end of target flight to enable target recovery at sea. The launched SAMs can be a Rolling Airframe Missile or the NATO Sea Sparrow Missile.

1.4.2 Anti-Surface Warfare Training

Anti-Surface Warfare (ASUW) is the PMAR that addresses combat (or interdiction) activities training by air, surface, or submarine forces against hostile surface ships and boats.

1.4.2.1 Surface-to-Surface Gunnery Exercise

Surface-to-Surface Gunnery Exercises (S-S GUNEX) take place in the open ocean to provide gunnery practice for Navy ship crews. Exercises can involve a variety of surface targets that are either stationary or maneuverable. Gun systems employed against surface targets include the 5", 76mm, 57mm, .50 caliber and the 7.62mm. A GUNEX lasts approximately one to two hours, depending on target services and weather conditions. All rounds fired are inert, containing no explosives.

1.4.2.2 Air-to-Surface Bombing Exercise

During an Air-to-Surface Bombing Exercise (BOMBEX A-S), fixed-wing aircraft deliver bombs against simulated surface maritime targets, typically a smoke float, with the goal of destroying or disabling enemy ships or boats.

MPA use bombs to attack surfaced submarines and surface craft that would not present a major threat to the MPA itself. A single MPA approaches the target at a low altitude. In most training exercises, the aircrew drops inert training ordnance, such as the Bomb Dummy Unit (BDU-45) on a MK-58 smoke float used as the target. Historically, ordnance has been released throughout W-237, just south of W-237, and in international waters in accordance with international laws, rules, and regulations. Annually, 120 pieces of ordnance, consisting of 10 MK-82 live bombs and 110 BDU-45 inert bombs, are dropped in the NWTRC. Each BOMBEX A-S can take up to 4 hours to complete.

1.4.2.3 Sinking Exercise

A Sinking Exercise (SINKEX) is typically conducted by aircraft, surface ships, and submarines in order to take advantage of a full size ship target and an opportunity to fire live weapons.

The target is typically a decommissioned combatant or merchant ship that has been made environmentally safe for sinking. In accordance with EPA permits, it is towed out to sea (at least 50 nm [92.6 km]) and set adrift at the SINKEX location in deep water (at least 1,000 fathoms [6,000 feet]) where it will not be a navigation hazard to other shipping. The Environmental Protection Agency (EPA) granted the Department of the Navy a general permit through the Marine Protection, Research, and Sanctuaries Act to transport vessels "for the purpose of sinking such vessels in ocean waters…" (40 CFR Part 229.2). Subparagraph (a)(3) of this regulation states "All such vessel sinkings shall be conducted in water at least 1,000 fathoms (6,000 feet) deep and at least 50 nautical miles from land."

Ship, aircraft, and submarine crews typically are scheduled to attack the target with coordinated tactics and deliver live ordnance to sink the target. Inert ordnance is often used during the first

stages of the event so that the target may be available for a longer time. The duration of a SINKEX is unpredictable because it ends when the target sinks, but the goal is to give all forces involved in the exercise an opportunity to deliver their live ordnance. Sometimes the target will begin to sink immediately after the first weapon impact and sometimes only after multiple impacts by a variety of weapons. Typically, the exercise lasts 4 to 8 hours, especially if inert ordnance such as 5-inch gun projectiles or MK-76 dummy bombs are used during the first hours. In the representative case, all of the ordnances listed in Table 1-2 are assumed expended; this represents the worst case of maximum exposure. If the hulk is not sunk by weapons, it will be sunk by Explosive Ordnance Disposal (EOD) personnel setting off demolition charges previously placed on the ship. Since the target may sink at any time during the exercise, the actual number of weapons used can vary widely.

Table 1-2: Types and Number of Ordnance Typically used in a SINKEX

Warfare Area	Ordnance	Number of Ordance Used per Event
Sinking Exercise (SINKEX)	MK82 Live Bomb	4
	MK83 Live Bomb	4
	MK84 Live Bomb	4
	HARM Missile	2
	AGM-114 Hellfire Missile	1
	AGM-65 Maverick Missile	3
	AGM-84 Harpoon Missile	3
	SLAM ER Missile	1
	5 in/62 Shell	500
	76 mm Shell	200
	MK48 ADCAP Torpedo	1

1.4.3 Mine Warfare Training

1.4.3.1 Mine Countermeasures

Naval EOD activities require proficiency in underwater mine neutralization. Mine neutralization activities consist of underwater demolitions designed to train personnel in the destruction of mines, unexploded ordnance (UXO), obstacles, or other structures in an area to prevent interference with friendly or neutral forces and non-combatants.

EOD units conduct underwater demolition training in Crescent Harbor Underwater EOD Range, Indian Island Underwater EOD Range, and Floral Point Underwater EOD Range. A 2.5 lb (1.1 kg) charge of C-4 is used, consisting of one surface or one subsurface detonation. No more than two detonations will take place annually at Crescent Harbor, and no more than one each at Indian Island and Floral Point. The total duration of the exercise is four hours for an underwater detonation and one hour for a surface detonation. Small boats such as MK-5, 7, or 9 (meters in length, respectively) Rigid Hull Inflatable Boats (RHIB) are used to insert personnel for underwater activities and either a helicopter (H-60) or RHIB is used for insertion for surface activities.

1.4.3.2 Mine Avoidance

Mine Avoidance: Mine avoidance exercises train ship and submarine crews to detect and avoid underwater mines. In the NWTRC, submarine crews will use the AN/BQS-15 high frequency active sonar to locate mine shapes in a training minefield in the PACNW OPAREA. Each mine avoidance exercise involves one submarine operating the AN/BQS-15 sonar for six hours to navigate through the training minefield. A total of seven mine avoidance exercises will occur in the NWTRC annually.

1.4.4 Naval Special Warfare and Explosive Ordnance Disposal Training

NSW forces (SEALs and Special Boat Units [SBUs]) train to conduct military activities in five Special Operations mission areas: unconventional warfare, direct action, special reconnaissance, foreign internal defense, and counterterrorism. Specific training events include:

1.4.4.1 Insertion/Extraction

Insertion/extraction activities hone individual skills in delivery and withdrawal of personnel and equipment using unconventional methods. Helicopter Rope Suspension Training (HRST) and parachute training are the principal insertion/extraction methods used by NSW and EOD teams at the NWTRC. This training activity occurs over land with no potential to impact marine mammals. Therefore, Insertion/Extraction activities are not carried forward for any further analysis of effects.

1.4.4.2 NSW Training Events

SEAL Delivery Vehicle Team ONE (SDVT-1) from Naval Special Warfare Group THREE (NSWG-3) in San Diego conducts underwater Unit Level Training (ULT) exercises twice a year within the NWTRC. For two to three weeks during these training detachments, SEALs conduct land-based training at Indian Island. The SDV is launched from Port Townsend, travels for approximately three hours, and delivers four to six SEALs to Indian Island where over-the-beach (OTB) and special reconnaissance training occurs. When the land portion of the training is complete—typically 2 days—the SDV returns and the SEALs transit back to Port Townsend via the SDV. The SDV runs on a quiet electric motor, with no sonar or other sound generated in the water. No explosives or live ordnance is used during any aspect of this training. This training activity has no potential to impact marine mammals and is not carried forward for any further analysis of effects.

1.4.5 Support Operations

Support Operations are activities that directly contribute to the execution and success of forces conducting PMARs. Within the NWTRC, Intelligence, Surveillance, and Reconnaissance (ISR) activities are conducted. Intelligence refers to the information and knowledge obtained through observation, investigation, analysis, or understanding. Surveillance and reconnaissance refer to the means by which the information is observed. Surveillance is the systematic observation of a targeted area or group, usually over an extended time, while reconnaissance is a specific mission performed to obtain specific data about a target.

ISR training is conducted by P-3C, MPA in W-237 and the PACNW OPAREA. Activities typically last six hours and involve a crew of 11 personnel. P-3 aircrews use a variety of intelligence gathering and surveillance methods, including visual, infrared, electronic, radar, and passive acoustic. EP-3 and EA-6B crews conduct ISR training as well, but to a lesser extent than

P-3C crews. Because ISR activities use only passive sensors, there is no potential for any impacts to marine mammals. Therefore, this activity is not carried forward for any further effects analysis.

Table 1-1 identifies training activities conducted in the NWTRC that may have a potential to cause incidental harassment of marine mammals. These activities are analyzed for impacts in subsequent sections of this LOA request.

1   **Table 1-1. Summary of NWTRC Training Events with Potential for Incidental Marine Mammal Harassment**

Exercise Type	ASW TRACKEX	Mine Avoidance	EER/IEER	MISSILEX	GUNEX	BOMBEX	SINKEX	MIW
Anticipated Takes	Yes	Yes	Yes	No	No	Yes	Yes	No
Sources/Weapons/ Rounds per year	SQS-53 MFA Sonar SQS-56 MFA Sonar AN/SSQ-62 Sonobuoy MK-48 Torpedo	AN/BQS-15 Sonar	SSQ-110A (6.72 lb NEW)	AIM-7 Sparrow AIM-9 Sidewinder AIM-120 AMRAAM NATO Sea Sparrow Rolling Airframe Missile	5 in gun 20 mm 25 mm 57 mm 76 mm .50 caliber	MK-82 Bombs (High Explosive) BDU-45 Bombs (Inert)	See Table 1.2	2.5 lb NEW
Explosion in or on water	No	No	Yes	No	No	Yes	Yes	Yes
Length of Exercise	1.5 hours	6 hours	6 hours	2-3 hours	2-3 hours	1 hour	8-48 hours	5 hours
Sonar hours, sonobuoys, torpedoes, detonations, or rounds per year	SQS-53 (Search Mode) = 39 hrs/year SQS-56 = 58.5 hrs/year SSQ-62 DICASS = 886 sonobuoys/year MK-48 Torpedo = 2 torpedoes/yr	AN/BQS-15 Sonar = 42.hrs/year	149 sonobuoys/year	13 AIM-7 missiles 9 AIM-9 missiles 7 AIM-120 missiles 8 NATO Sea Sparrow *or* 8 Rolling Airframe Missiles	5 in gun (2,463 rounds) 20 mm (16,000 rounds) 25 mm (31,500 rounds) 57 mm (1,260 rounds) 76 mm (720 rounds) .50 caliber (117,000 rounds)	10 MK-82 Bombs (High Explosive) 110 BDU-45 Bombs (Inert)	See Table 1.2	4/year
Number Exercises per Year	65	7	12	28	340	30	2	4
Area Used	Pacific Northwest Surface/ Subsurface OPAREA	Pacific Northwest Surface/ Subsurface OPAREA	Pacific Northwest Surface/ Subsurface OPAREA	Pacific Northwest Surface/ Subsurface OPAREA	Pacific Northwest Surface/ Subsurface OPAREA	Pacific Northwest Surface/ Subsurface OPAREA	Pacific Northwest Surface/ Subsurface OPAREA	EOD Crescent Harbor, EOD Indian Island, EOD Floral Point
Months of Year conducted	Year Round	Year Round	Year Round	Year Round	Year Round	Year Round	Year Round	Year Round

2   Notes:
3   For ASW TRACKEX: 53 and 56 number equates to annual hours of use; buoys number equates to annual number of sonobuoys used; MK48 number equates to annual number of MK48 torpedoes used.
4   NEW = Net explosive weight, SINKEX = Sinking exercise, GUNEX = Gunnery exercise (includes S-S and S-A), MISSILEX = Missile exercise (includes A-A and S-A)

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2 LOCATION OF ACTIVITIES

2.1 Overview of the Northwest Training Range Complex

Training activities would be conducted in the Northwest Training Range Complex (NWTRC) throughout the year from October 2009 through September 2014. The range complex includes ranges and airspace that extend west to 250 nautical miles (nm) (463 kilometers [km]) beyond the coast of Northern California, Oregon, and Washington and east to Idaho. The components of the NWTRC encompass 122,400 nm^2 (420,163 km^2) of surface/subsurface ocean operating areas (OPAREAs), 46,048 nm^2 (157,928 km^2) of special use airspace (SUA), and 875 acres (354 hectares) of land. For range management and scheduling purposes, the NWTRC is divided into numerous sub-component ranges or training areas used to conduct training and RDT&E of military hardware, personnel, tactics, munitions, explosives, and electronic combat systems, as described in detail in this section. As this LOA application is inherently tied to the surface/subsurface OPAREAs of the NWTRC, only those areas are discussed in detail below.

NWTRC Ocean OPAREA. The ocean areas of the range complex include surface and subsurface operating areas extending generally west from the coastline of Northern California, Oregon, and Washington for a distance of approximately 250 nm (463 km) into international waters.

Military activities in the NWTRC occur (1) on the ocean surface, (2) under the ocean surface, (3) in the air, and (4) on land. A summary of the sea, and undersea spaces addressed in this LOA application is provided in Table 2-1. To aid in the description of the range complex, the ranges are divided into three major geographic and functional subdivisions. Each of the individual ranges falls into one of these three major range subdivisions:

- The Offshore Area. This area consists of sea, and undersea ranges, OPAREAs, and military training activities in waters out to approximately 250 nautical miles west of the coastline.

- The Inshore Area includes all sea, and undersea ranges and OPAREAs inland of the coastline and including Puget Sound, but excludes Naval Weapons Systems Training Facility (NWSTF) Boardman and its associated ranges that are used exclusively by Explosive Ordnance Disposal (EOD)/Naval Special Warfare (NSW) forces.

- The EOD ranges and OPAREAs primarily are land, sea, and undersea ranges used by NSW and EOD forces.

Table 2-1 provides an overview of each range within these areas. Table 2-2 summarizes the major component areas of the NWTRC Offshore Areas, and Figure 1-1 depicts the three major geographic divisions of the ranges.

Table 2-1: Summary of the Air, Sea, Undersea, and Land Space of the NWTRC

Area Name	Sea Space (nm^2)	Undersea Space (nm^2)
Offshore Area	122,400	122,400
Inshore Area	61	61
EOD/NSW Ranges	0.4	0.4
TOTAL	**122,421**	**122,400**

Source: 366 Report to Congress

Table 2-2: NWTRC Offshore Areas

Area Designation	Description
Pacific Northwest Ocean Surface/Subsurface Operating Area (PACNW OPAREA)	The Pacific Northwest Ocean Surface/Subsurface Operating Area (PACNW OPAREA) extends from the northern coast of California to the Strait of Juan de Fuca, from the coast line westward to 130° West longitude.
Warning Area 237 (W-237 [A-H, J])	W-237 airspace extends westward starting 3 nm (5.6 km) offshore from the coast of Washington State and is divided into nine (9) areas (A-H, and J) of designated SUA.
Warning Area 570 (W-570)	W-570 is a smaller warning area off the central coast of Oregon.
Warning Area 93 (W-93 [A/B])	Warning Area 93 is located off the coast of Oregon, approximately 10 nm 19 km) south of W-570.

2.1.1 NWTRC Offshore Area Overview

The Pacific Northwest (PACNW) OPAREA serves as maneuver water space for ships and submarines to conduct training and to use as transit lanes. It extends from the Strait of Juan de Fuca in the north, to approximately 50 nm (93 km) south of Eureka, California in the south, and from the coast line of Washington, Oregon, and California westward to 130° West longitude.

The PACNW OPAREA is approximately 510 nm (945 km) in length from the northern boundary to the southern boundary, and 250 nm (463 km) from the coastline to the western boundary at 130° W longitude. Total surface area of the PACNW OPAREA is 122,400 nm^2 (420,163 km^2). Commander Submarine Force, U.S. Pacific Fleet (COMSUBPAC) Pearl Harbor manages this water space as transit lanes for U.S. submarines. While the sea space is ample for all levels of Navy training, no infrastructure is in place to support training. There are no dedicated training frequencies, no permanent instrumentation, no meteorological and oceanographic activities (METOC) system, and no Opposition Forces (OPFOR) or Electronic Combat (EC) target systems. In this region of the Pacific Ocean, storms and high sea states can create challenges to surface ship training between October and April. In addition, strong undersea currents in the PACNW make it difficult to place bottom-mounted instrumentation such as hydrophones.

Undersea Space

The Offshore Area undersea space lies beneath the PACNW OPAREA as described above. The bathymetry chart depicts a 100 fathom (600 foot) curve parallel to the coastline approximately 12 nm (22 km) to sea, and in places 20 nm (37 km) out to sea. The area of deeper water of more than 100 fathoms (600 feet, 182 m) is calculated to be approximately 115,800 nm^2 (397,194 km^2, while the shallow water area of less than 100 fathoms (600 ft, 182 m) is all near shore and amounts to approximately 6,600 nm² (22,638 km^2).

2.1.2 NWTRC Inshore Area

NWTRC Inshore Areas include land ranges, airspace, and two surface/subsurface restricted areas; Navy 7 and 3. Activities conducted in each of these areas are not expected to have any potential impact to marine mammals are not discussed further in this application.

2.1.3 EOD Ranges

EOD units located in the NWTRC conduct underwater detonations as part of mine countermeasure training. This training is conducted at one of three locations: Crescent Harbor Underwater EOD Range, offshore from the Seaplane Base at Naval Air Station Whidbey Island; at the Floral Point Underwater EOD Range, located in Hood Canal near NAVBASE Kitsap-Bangor; and the Indian Island Underwater EOD Range, adjacent to Indian Island. Figures 2-1 and 2-2 depict the EOD Ranges.
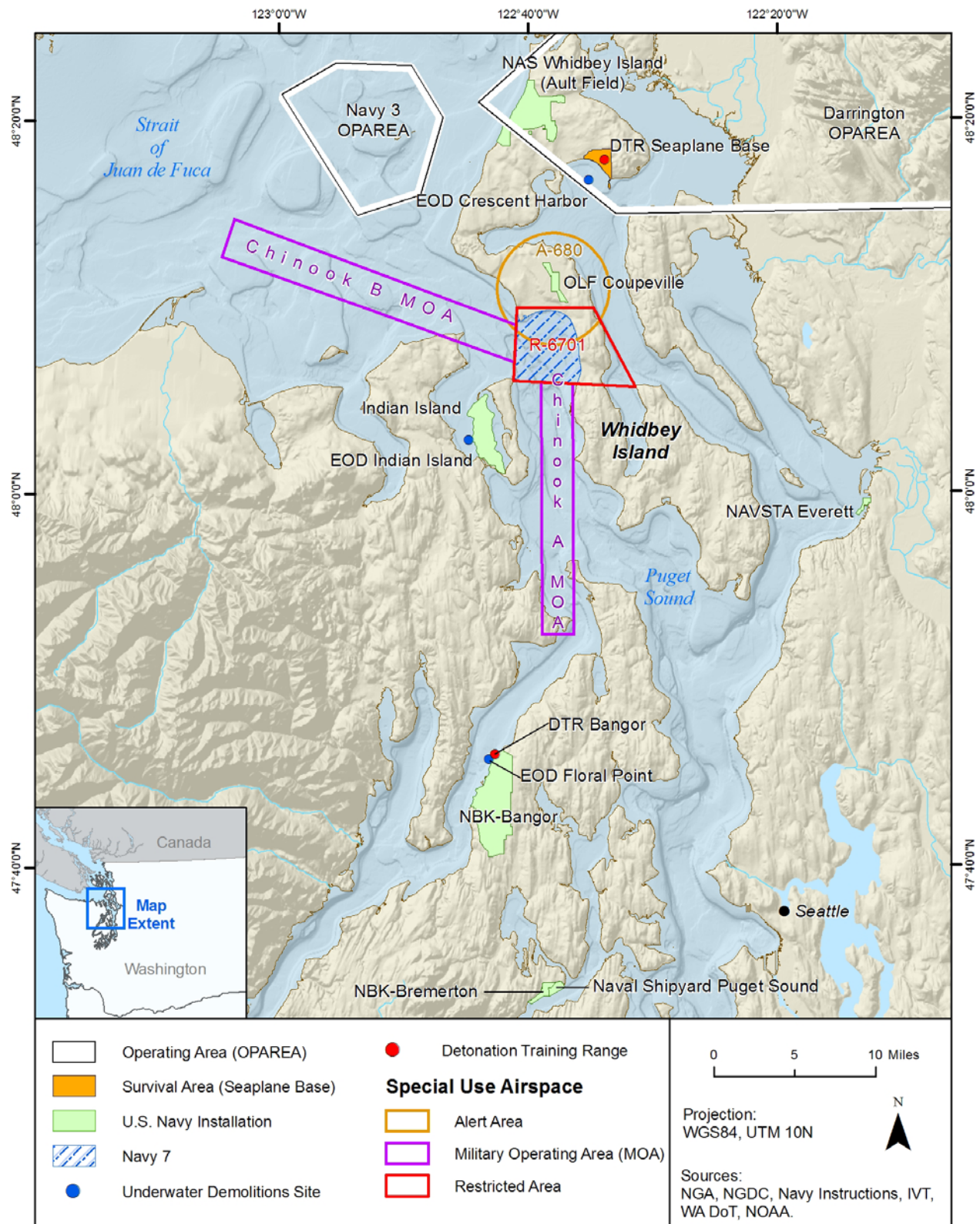
Figure 2-1: NWTRC Inshore Area (Puget Sound)
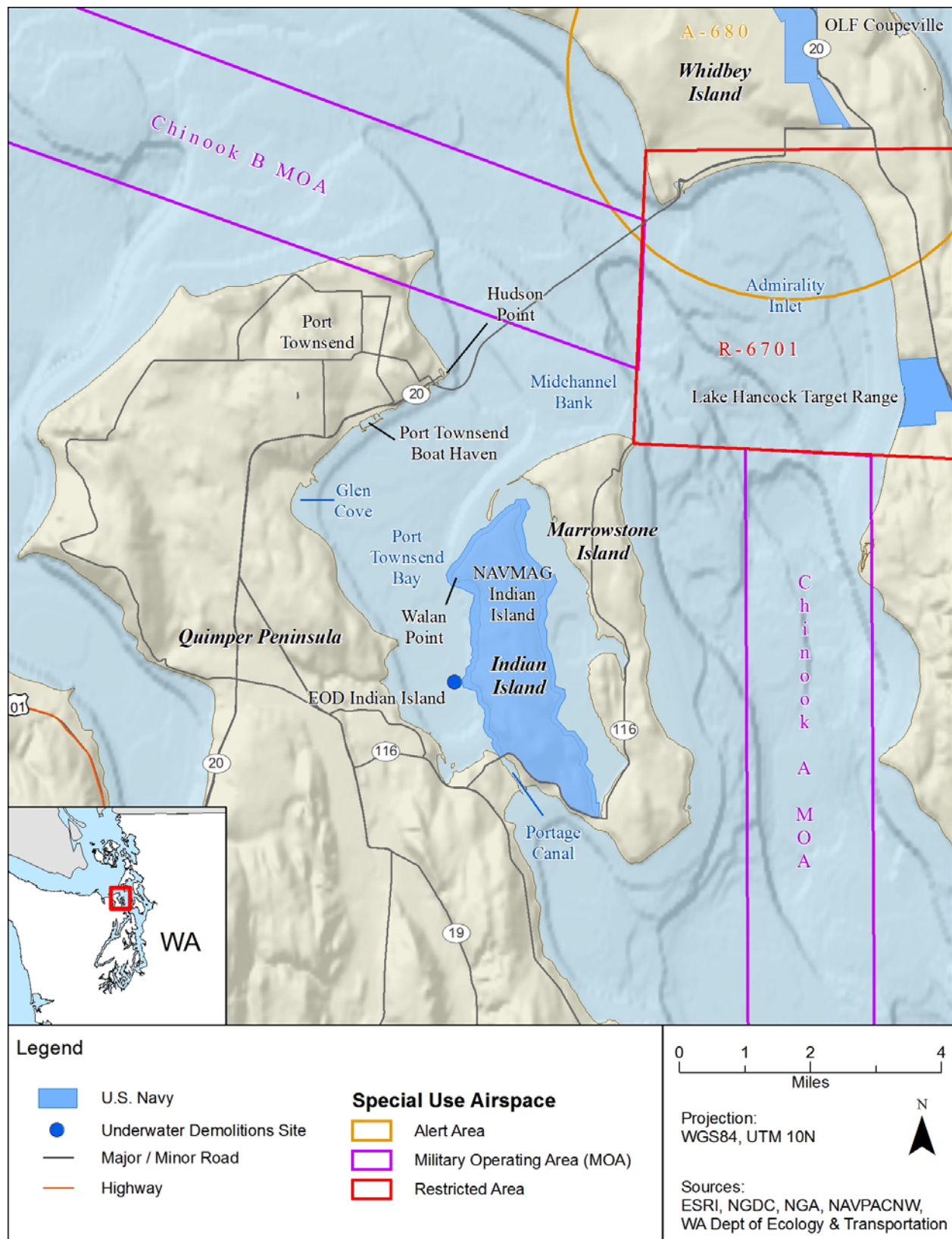
1
2 **Figure 2-2: NWTRC Inshore Area (Indian Island – Port Townsend)**

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3 MARINE MAMMALS

There are 33 marine mammal species or separate stocks with possible or confirmed occurrence in the marine waters of the Pacific Northwest (PACNW) and within the Northwest Training Range Complex (NWTRC) (Carretta et al. 2007, Angliss and Outlaw 2008). As shown in Table 3-1, there are 27 cetacean species (whales, dolphins, and porpoises), five pinnipeds (sea lions, fur seals and true seals) and one sea otter species.

3.1 Species Summaries and Life History

The California Current passes through the NWTRC, creating a mixing of temperate and tropical waters, and making this area one of the most productive ocean systems in the world (Department of the Navy [DoN] 2002a). Because of this productive environment, there is a rich marine mammal fauna, as evidenced in abundance and species diversity (Leatherwood et al. 1988; Bonnell and Dailey 1993). In addition to many marine mammal species that live here year-round and use the region's coasts and islands for breeding and hauling out, there is a community of seasonal residents and migrants. The narrow continental shelf along the Pacific coast and the presence of the cold California Current sweeping down from Alaska allows cold-water marine mammal species to reach nearshore waters as far south as Baja California.

Thirty-three marine mammal species or populations/stocks have confirmed or possible occurrence within the NWTRC, including six species of baleen whales (mysticetes), 21 species of toothed whales (odontocetes), five species of seals and sea lions (pinnipeds), and the sea otter (mustelids). Table 3-1 summarizes their abundance, Endangered Species Act (ESA) status, population trends, and occurrence in the area. Most of these species are listed as "common" in Table 3-1, indicating that they occur routinely, either year-round or during annual migrations into or through the area. The other species are indicated as "rare" because of sporadic sightings or as "very rare" animals documented once or twice as appearing outside their normal range. All of the species that occur in the NWTRC are either cosmopolitan (occur worldwide), or associated with the temperate and sub-Arctic oceans (Leatherwood et al. 1988).

Temperate and warm-water toothed whales often change their distribution and abundance as oceanographic conditions vary both seasonally (Forney and Barlow 1998) and interannually (Forney 2000). Forney and Barlow (1998) noted significant north/south shifts in distribution for Dall's porpoises, common dolphins, and Pacific white-sided dolphins, and they identified significant inshore/offshore differences for northern right whale dolphins and humpback whales. Several authors have noted the impact of the El Niño events of 1982/1983 and 1997/1998 on marine mammal occurrence patterns and population dynamics in the waters off California (Wells et al. 1990; Forney and Barlow 1998; Benson et al. 2002).

The distribution of some marine mammal species is based on the presence of salmon, an important prey source. Seals and sea lions congregate near areas where migrating salmon run. For example, in the San Juan Islands, harbor seals (*Phoca vitulina richardii*) congregate near a constricted channel where incoming tidal currents funnel migrating salmon (Zamon 2001). In Oregon, harbor seals wait for chum salmon runs during the incoming tide near a constriction in Netarts Bay (Brown and Mate 1983). During the summer, resident killer whales (*Orcinus orca*) congregate at locations associated with high densities of migrating salmon (Heimlich-Boran 1986; Nichol and Shackleton 1996; Olson 1998; National Marine Fisheries Service [NMFS]

2005i). Their strong preference for Chinook salmon may influence the year-round distribution patterns of resident killer whales in the NWTRC (Ford and Ellis 2005).

3.2 Data Sources

The *Marine Resources Assessment (MRA) for the Pacific Northwest Operating Area* (DoN 2006) was used as a baseline for describing the physical, biological, marine, terrestrial, and cultural features particular to this region. These descriptions are presented in Section 4. For some species, the NWTRC constitutes a large portion of their total range. Other species, such as the gray whale (*Eschrichtius robustus*), only transit through the area during annual migrations between northern feeding grounds and breeding lagoons in Mexico. The MRA was supplemented during the development of this Letter of Authorization (LOA) application to update information since the MRA was published in 2006. This supplementation included a detailed search of multiple peer-review scientific journals, and government reports. Several search engines were used in this process including Science Direct®, High Wire Press®, Directory of Open Access Journals, the Journal of the Acoustical Society of America-Online (JASA-O). Science Direct® databases provide access to more than 8 million articles in over 2,000 journals focused on the physical sciences and engineering, life sciences, health sciences, and social sciences and humanities. High Wire Press® offers access to nearly 4.3 million articles published by approximately 1,040 journals. Topics for journals in these databases include biological, social, medical, and physical sciences and the humanities. The Directory of Open Access Journals includes peer-reviewed scientific and scholarly publications that are available to the public free of charge. The searches of each database included general queries in the resource areas of and potential effects to marine species (marine mammals, sea turtles, fish, and birds), socioeconomics (fisheries, tourism, boating, and diving), natural resources (oil and gas), artificial reefs, whale and dolphin watching, and cultural resources. Finally, JASA-O offers search capabilities for and access to articles as early as 1929. Searches for articles available from this journal included focused information on hearing capabilities and potential effects on marine species such as marine mammals, sea turtles, manatees, fish, and diving birds. In addition to search engines and science information portals, a direct review was conducted of other journals that regularly publish marine mammal related articles (e.g., Marine Mammal Science, Canadian Journal of Zoology, Journal of Acoustical Society of America, Journal of Zoology, Aquatic Mammals). References were also obtained from previous environmental documents where applicable, and from mitigation and regional monitoring reports. The original reference authors were contacted directly if necessary to clarify particular points presented in a paper or gain additional insight into the data analysis.

3.3 Data Quality and Availability

Recent advances in marine mammal tagging and tracking have contributed to the growth of biological information including at-sea movements and diving behavior. Given the development of this new technology and difficulties in placing tags on marine mammals in the wild, the body of literature and sample size, while growing, is still relatively small. For difficult to study marine mammals such as an audiogram from a single Gervais beaked whale stranded from natural causes (Cook et al. 2006), even a sample size of one contributes new information that had not been available previously. Additional information was also solicited from acknowledged experts within academic institutions and government agencies such as Southwest Fisheries Science Center, NMFS with expertise in marine mammal biology, distribution, and acoustics.

3.4 Species and Occurrence

3.4.1 Threatened and Endangered Marine Mammal Species

Stocks of all species listed as endangered under the ESA are automatically considered 'depleted' and 'strategic' under the Marine Mammal Protection Act (MMPA). The specific definition of a strategic stock is complex, but in general it is a stock for which human activities may be having a deleterious effect on the population and that population may not be sustainable.

In addition to those species listed under the ESA, all marine mammals are protected under the MMPA of 1972, amended 1994, administered by the National Oceanic and Atmospheric Association (NOAA) Fisheries and the United States Fish and Wildlife Serveice (USFWS).

Detailed information for all species is included in Section 4.

Cetaceans

Six cetacean species regularly occur within the NWTRC and are listed as Endangered under the ESA. These include the blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaeangliae*), sei whale (*Balaenoptera borealis*), sperm whale (*Physeter macrocephalus*), and the southern resident killer whale (*Orcinus orca*).

Seals and Sea Otter

One pinniped species regularly occurs within the NWTRC and is listed as Threatened under the ESA, the Steller sea lion (*Eumetopias jubatus*). The southern sea otter (*Enhydra lutris nereis*) is also listed as threatened under ESA. The southern sea otter is also "fully protected" under California Fish and Game Code (FGC) §4700.

3.4.2 Non-Threatened and Non-Endangered Cetaceans

Baleen Whales

There are two non-listed species of baleen whales with confirmed or possible occurrence in the NWTRC. Gray whales were removed from the endangered list in 1994 because of an increase in population numbers (Carretta et al. 2005). Gray whales occur in the Pacific Northwest Ocean Surface/Subsurface Operating Area (PACNW OPAREA) and in the Puget Sound throughout the year. Minke whales are observed year-round in Puget Sound, with a peak in abundance between July and September (Everitt et al. 1979; Osborne et al. 1988; Dorsey et al. 1990). There is also a band of primary occurrence on the outer coast. The California/Oregon/ Washington stock of minke whales has been reclassified as non-strategic (Barlow et al. 1998; Caretta et al. 2005).

Toothed Whales

There are 23 non-listed species of toothed whales with confirmed or possible occurrence in the NWTRC. From Table 3-1, the most common toothed whales within NWTRC include the Dall's porpoise (*Phocoenoides dalli*), harbor porpoise (*Phocoena phocoena*), northern right whale dolphin (*Lissodelphis borealis*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), short-beaked common dolphin (*Delphinus delphis*), and striped dolphin (*Stenella coeruleoalba*). Dolphin species typically are the most numerous cetacean species within the NWTRC area (Dohl et al. 1981, Dohl et al. 1986, Bonnell and Dailey 1993, Carretta et al. 2000, Ferguson and Barlow 2001, Soldevilla et al. 2006, Carretta et al. 2007).

The occurrence and abundance of beaked whale species off California, Oregon, and Washington (Ziphiidae) is less certain given the cryptic behavior of these species and the difficulties of accurate at-sea species-level identification. Beaked whales potentially found within NWTRC include Baird's beaked whale (*Berardius bairdii*) and Cuvier's beaked whale (*Ziphius cavirostris*). Mesoplodont beaked whales of the Family Ziphiidae that potentially occur in the NWTRC include Hubb's beaked whale (*Mesoplodon carlhubbsi*), Blainville's beaked whale (*M. densirostris*), Perrin's beaked whale (*M. perrini*), lesser beaked whale (*M. peruvianus*), Stejneger's beaked whale (*M. stejnegeri*), and gingko-toothed beaked whale (*M. gingkodens*), but are presented collectively as *Mesoplodon* sp. in Table 3-1 and the remainder of this LOA.

3.4.3 Non-Threatened and Non-Endangered Seals and Sea Lions

There are four non-listed species of pinnipeds with confirmed or possible occurrence in the NWTRC. From Table 3-1, these include the California sea lion (*Zalophus californianus*), harbor seal (*Phoca vitulina*), northern elephant seal (*Mirounga angustirostris*) and the Northern fur seal (*Callorhinus ursinus*). The northern elephant seal is "fully protected" under California Fish and Game Code (FGC) §4700.

3.4.4 Listed Marine Mammal Species Excluded from Analysis

The North Pacific right whale is classified as endangered under the ESA. Although there is designated critical habitat for this species in the western Gulf of Alaska and an area in the southeastern Bering Sea (NMFS 2006h), there is no designated critical habitat for this species within the NWTRC. Census data are too limited to suggest a population trend for this species. In the western North Pacific, the population may number in the low hundreds (Brownell et al. 2001; Clapham et al. 2004). Right whales were probably never common along the west coast of North America (Scarff 1986; Brownell et al. 2001). Historical whaling records provide virtually the only information on North Pacific right whale distribution. Presently, sightings are extremely rare, occurring primarily in the Okhotsk Sea and the eastern Bering Sea (Brownell et al. 2001; Shelden et al. 2005; Shelden and Clapham 2006; Wade et al. 2006). There were no sightings of North Pacific right whales during ship surveys conducted off California, Oregon, and Washington from 1991 through 2005 (Barlow and Forney 2007). The area of densest concentration in the Gulf of Alaska is east from 170°W to 150°W and south to 52°N (Shelden and Clapham 2006). Based upon the extremely low probability of encountering this species anywhere in the coastal and offshore waters in the NWTRC, this species will not be included in this analysis

Table 3-1: Summary of Marine Mammal Species, Status, and Abundance in the NWTRC.

Common Name Species Name	Abundance (CV)	Stock	Calculated Density (animals per km^2)	Population Trend	Occurrence	Designated Critical Habitat	Warm Season May-Oct	Cold Season Nov-Apr
ESA Listed Baleen Whales								
Blue whale[1,2,3] *Balaenoptera musculus*	1,186 (0.19)	Eastern North Pacific	0.0005*	May be increasing	Common	None in North Pacific	Yes	No
Fin whale [1,2,3] *Balaenoptera physalus*	3,454 (0.27)	California, Oregon, and Washington	0.0014*	May be increasing	Common	None	Yes	Yes
Humpback whale[1,2,3] *Megaptera novaeangliae*	1,396 (0.15)	Eastern North Pacific	0.0007*	Increasing	Common	None	Yes	No
Sei whale[1,2,3] *Balaenoptera borealis*	43 (0.61)	Eastern North Pacific	0.000115[c] 0.000182[d]	May be increasing	Common	None	Yes	No
ESA Listed Toothed Whales								
Sperm whale[1,2,3] *Physeter macrocephalus*	2,265 (0.34)	California, Oregon, and Washington, Offshore	0.0026*	Unknown	Common	None	Yes	Yes
Southern resident killer whale[1,2] *Orcinus orca*	89	Eastern North Pacific, Southern Resident	--	Increasing	Common	Yes, Puget Sound and vicinity	Yes	Yes
ESA Listed Pinniped								
Steller sea lion[2,4] *Eumetopias jubatus*	48,519	Eastern	0.000011 / 0.011[b]	Decreasing	Common	Yes, rookeries in Oregon and California	Yes	Yes
ESA Listed Mustilid								
Sea Otter[2,4] *Enhydra lutris*	2,359 360	California Washington	--	Increasing Increasing	Common	None	Yes	Yes
Non-ESA Listed Baleen Whales								
Gray whale *Eschrichtius robustus*	18,178	Eastern North Pacific	--	Increasing	Common	--	No	Yes
Minke whale *Balaenoptera acutorostrata*	898 (0. 65)	California, Oregon, and Washington	0.000655[c] 0.000395[d]	No trends	Common	--	No	Yes

Table 3-1: Summary of Marine Mammal Species, Status, and Abundance in the NWTRC (continued).

Common Name Species Name	Abundance (CV)	Stock	Calculated Density (animals per km²)	Population Trend	Occurrence	Designated Critical Habitat	Warm Season May-Oct	Cold Season Nov-Apr
Non-ESA Listed Toothed Whales								
Baird's beaked whale *Berardius bairdii*	313 (0.55)	California, Oregon, and Washington	0.001614[c] 0.000775[d]	Unknown	Common	--	Yes	Yes
Bottlenose dolphin offshore *Tursiops truncatus*	3,257 (0.43)	California, Oregon, Washington, Offshore	0.000515[c]	No trend	Very Rare	--	Yes	Yes
Cuvier's beaked whale *Ziphius cavirostris*	2,171 (0.75)	California, Oregon, and Washington	0.003038[c]	Unknown	Common	--	Yes	Unknown
Dall's porpoise *Phocoenoides dalli*	57,549 (0.34)	California, Oregon, and Washington	0.0970[*]	Unknown	Common	--	No	Yes
Dwarf sperm whale *Kogia sima*	unknown	California, Oregon, and Washington	--	Unknown	Very Rare	--	Unknown	Yes
Harbor porpoise *Phocoena phocoena*	17,763 (0.39) 37,745 (0.38) 10,682 (0.38)	Northern California/ Southern Oregon Washington/ Oregon Coastal Washington Inland Waters	--	Stable Stable Stable	Common	--	Yes	Yes
Killer whale offshore *Orcinus orca*	422	Eastern North Pacific Offshore	--	Unknown	Common	--	No	Yes
Killer whale transient *Orcinus orca*	346	Eastern North Pacific Transient	--	Unknown	Common	--	No	Yes
Mesoplodont beaked whales[a] *Mesoplodon sp.*	1024 (0.77)	Washington, Oregon, and California	0.00135[c] 0.001321[d]	Unknown	Rare	--	Unknown	Unknown
Northern right whale dolphin *Lissodelphis borealis*	15,305 (0.232)	California, Oregon, and Washington	0.0014[*]	No trend	Common	--	Yes	Yes
Pacific white-sided dolphin *Lagenorhynchus obliguidens*	25,233 (0.25)	California, Oregon, and Washington	0.0441[*]	No trend	Common	--	Yes	Yes

Table 3-1: Summary of Marine Mammal Species, Status, and Abundance in the NWTRC (continued).

Common Name Species Name	Abundance (CV)	Stock	Calculated Density (animals per km^2)	Population Trend	Occurrence	Designated Critical Habitat	Warm Season May-Oct	Cold Season Nov-Apr
Non-ESA Listed Toothed Whales (continued)								
Pygmy sperm whale *Kogia breviceps*	Unknown	California, Oregon, and Washington	0.001232[c] 0.000504[d]	Unknown	Common	--	Unknown	Unknown
Risso's Dolphin *Grampus griseus*	12,093 (0.24)	California, Oregon, and Washington	0.013222[c] 0.004014[d]	No trend	Common	--	Yes	Yes
Short-beaked common dolphin *Delphinus delphis*	487,622 (0.26)	California, Oregon, and Washington	0.1570[*]	Varies by oceanographic conditions	Common	--	Yes	Yes
Short-finned pilot whale *Globicephala macrorhynchus*	245 (0.97)	California, Oregon, and Washington	--	Unknown	Rare	--	Unknown	Unknown
Striped dolphin *Stenella coeruleoalba*	23,883 (0.44)	California, Oregon, and Washington	0.0000497[c] 0.015653[d]	No trend	Rare	--	No	Unknown
Non-ESA Listed Pinnipeds								
California sea lion *Zalophus californianus*	238,000	U.S.	--	Increasing	Common	--	Yes	Yes
Harbor seal *Phoca vitulina*	34,233; 24,732 (0.12); 14,612 (0.15)	California; Washington/ Oregon Coastal; Washington Inland	--	Increasing; Stable; Stable	Common	--	Yes	Yes
Northern elephant seal *Mirounga angustirostris*	124,000	California Breeding	--	Increasing	Common	--	Yes	Yes
Northern fur seal *Callorhinus ursinus*	721,935	Eastern Pacific	--	Increasing	Common	--	Yes	Yes

Endangered Species Act. Notations [1]endangered. 2threatened. MMPA designations [3]Strategic stock, [4]Depleted

a/ Due to identification difficulty on cetacean surveys, the six possible mesoplodont whales in this region are presented at the genus level.

[b] Warm season / Cold Season;; [*] Estimated for NWTRC Study Area (DoN 2007a) [c] Northern California Density (from SAR) [d] Washington/Oregon Density (from SAR)

SOURCE : Barlow and Forney 2007, Angliss and Outlaw 2008, Carretta et al 2007.DoN, 2007

3.5 Estimated Marine Mammal Densities

Marine mammal species occurring off Washington, Oregon, and California include baleen whales (mysticetes), toothed whales (odontocetes), seals and sea lions (commonly referred to as pinnipeds), and sea otters. Baleen and toothed whales, collectively known as cetaceans, spend their entire lives in the water and spend most of the time (>90% for most species) entirely submerged below the surface. When at the surface, cetacean bodies are almost entirely below the water's surface, with only the blowhole exposed to allow breathing. This makes cetaceans difficult to locate visually and also exposes them to underwater noise, both natural and anthropogenic, essentially 100% of the time because their ears are nearly always below the water's surface. Seals and sea lions (pinnipeds) spend significant amounts of time out of the water during breeding, molting and hauling out periods. In the water, pinnipeds spend varying amounts of time underwater, as some species regularly undertake long, deep dives (e.g., elephant seals) and others are known to rest at the surface in large groups for long amounts of time (e.g., California sea lions). When not actively diving, pinnipeds at the surface often orient their bodies vertically in the water column and often hold their heads above the water surface. Consequently, pinnipeds may not be exposed to underwater sounds to the same extent as cetaceans. Sea otters generally do not spend significant amounts of time on land, but they also often hold their heads above the water's surface, reducing the amount of exposure to underwater noise.

For the purposes of this analysis, we have adopted a conservative approach to underwater noise and marine mammals:

Cetaceans – assume 100% of time is spent underwater and therefore exposed to noise

Pinnipeds – adjust densities to account for time periods spent at breeding areas, haulouts, etc.; but for those animals in the water, assume 100% of time is spent underwater and therefore exposed to noise

Sea otters – assume 100% of time is spent underwater and therefore exposed to underwater noise.

3.5.1 Derivation of Marine Mammal Density Estimates for NWTRC

Density estimates for cetaceans were obtained from the *Marine Mammal and Sea Turtle Density Estimates for the Pacific Northwest Study Area* (DoN 2007a). The abundance of most cetaceans was derived from shipboard surveys conducted by the Southwest Fisheries Science Center in 1991, 1993, 1996, 2001, and 2005 (Barlow 1995; Barlow 2003; Barlow and Forney 2007). These estimates are used to develop NMFS Stock Assessment Reports (Carretta et al 2007); interpret the impacts of human-caused mortality associated with fishery bycatch, ship strikes, and other sources; and evaluate the ecological role of cetaceans in the eastern North Pacific. In the density study, predictive species-habitat models were built for species with sufficient numbers of sightings to estimate densities for the NWTRC. For species with insufficient numbers of sightings, density estimates were obtained from Barlow and Forney (2007).

3.5.2 Depth Distribution

There are limited depth distribution data for most marine mammals. This is especially true for cetaceans, as they must be tagged at-sea and by using a tag that either must be implanted in the skin/blubber in some manner or adhere to the skin. There is slightly more data for some pinnipeds, as they can be tagged while on shore during breeding or molting seasons and the tags

can be glued to the pelage rather than implanted. There are a few different methodologies/techniques that can be used to determine depth distribution percentages, but by far the most widely used technique currently is the time-depth recorder. These instruments are attached to the animal for a fairly short period of time (several hours to a few days) via a suction cup or glue, and then retrieved immediately after detachment or when the animal returns to the beach. Depth information can also be collected via satellite tags, sonic tags, digital tags, and, for sperm whales, via acoustic tracking of sounds produced by the animal itself.

There are somewhat suitable depth distribution data for a few marine mammal species. Sample sizes are usually extremely small, nearly always fewer than 10 animals total and often only one or two animals. Depth distribution information often must be interpreted from other dive and/or preferred prey characteristics. Depth distributions for species for which no data are available are extrapolated from similar species.

3.5.3   Density And Depth Distribution Combined

Density is nearly always reported for an area, e.g., animals/km^2. Analyses of survey results using Distance Sampling techniques include correction factors for animals at the surface but not seen as well as animals below the surface and not seen. Therefore, although the area (e.g., km^2) appears to represent only the surface of the water (two-dimensional), density actually implicitly includes animals anywhere within the water column under that surface area. Density assumes that animals are uniformly distributed within the prescribed area, even though this is likely rarely true. Marine mammals are usually clumped in areas of greater importance, for example, areas of high productivity, lower predation, safe calving, etc. Density can occasionally be calculated for smaller areas that are used regularly by marine mammals, but more often than not there are insufficient data to calculate density for small areas. Therefore, assuming an even distribution within the prescribed area remains the norm.

Assuming that marine mammals are distributed evenly within the water column is not accurate. The ever-expanding database of marine mammal behavioral and physiological parameters obtained through tagging and other technologies has demonstrated that marine mammals use the water column in various ways, with some species capable of regular deep dives (<800 m) and others regularly diving to <200 m, regardless of the bottom depth. Assuming that all species are evenly distributed from surface to bottom is almost never appropriate and can present a distorted view of marine mammal distribution in any region.

By combining marine mammal density with depth distribution information, a more accurate three-dimensional density estimate is possible. These 3-D estimates allow more accurate modeling of potential marine mammal exposures from specific noise sources.

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4 ASSESSMENT OF MARINE MAMMAL SPECIES OR STOCKS THAT COULD POTENTIALLY BE AFFECTED

Marine mammals inhabit most marine environments from deep ocean canyons to shallow estuarine waters. They are not randomly distributed. Marine mammal distribution is affected by demographic, evolutionary, ecological, habitat-related, and anthropogenic factors (Bowen et al. 2002; Bjørge, 2002; Forcada, 2002; Stevick et al. 2002). Section 4.1 includes a general description of the marine mammals that may occur within the Northwest Training Range Complec (NWTRC). Endangered marine mammals are presented first, followed by threatened species and non-endangered species.

Marine mammal movements are often related to feeding or breeding activity (Stevick et al. 2002). A migration is the periodic movement of all, or significant components of an animal population from one habitat to one or more other habitats and back again. Migration is an adaptation that allows an animal to monopolize areas where favorable environmental conditions exist for feeding, breeding, and/or other phases of the animal's life history. Some baleen whale species, such as humpback whales, make extensive annual migrations to low-latitude mating and calving grounds in the winter and to high-latitude feeding grounds in the summer (Corkeron and Connor, 1999). Cetacean movements can also reflect the distribution and abundance of prey (Gaskin, 1982; Payne et al. 1986; Kenney et al. 1996). Cetacean movements have also been linked to indirect indicators of prey, such as temperature variations, sea-surface chlorophyll-a concentration, and features such as bottom depth (Fiedler, 2002). Oceanographic conditions such as upwelling zones, eddies, and turbulent mixing can create regionalized zones of enhanced productivity that are translated into zooplankton concentrations, and/or entrain prey.

4.1 Marine Mammal Hearing and Vocalization Summary

4.1.1 Cetaceans

Cetaceans have an auditory anatomy that follows the basic mammalian pattern, with some changes to adapt to the demands of hearing in the sea. The typical mammalian ear is divided into an outer ear, middle ear, and inner ear. The outer ear is separated from the inner ear by a tympanic membrane, or eardrum. In terrestrial mammals, the outer ear, eardrum, and middle ear transmit airborne sound to the inner ear, where the sound waves are propagated through the cochlear fluid. Since the impedance of water is close to that of the tissues of a cetacean, the outer ear is not required to transduce sound energy as it does when sound waves travel from air to fluid (inner ear). Sound waves traveling through the inner ear cause the basilar membrane to vibrate. Specialized cells, called hair cells, respond to the vibration and produce nerve pulses that are transmitted to the central nervous system. Acoustic energy causes the basilar membrane in the cochlea to vibrate. Sensory cells at different positions along the basilar membrane are excited by different frequencies of sound (Pickles 1998). Baleen whales have inner ears that appear to be specialized for low-frequency hearing. Conversely, dolphins and porpoises have ears that are specialized to hear high frequencies.

Marine mammal vocalizations often extend both above and below the range of human hearing; vocalizations with frequencies lower than 18 Hertz (Hz) are labeled as infrasonic and those higher than 20 kHz as ultrasonic (National Research Council [NRC] 2003; Figure 4-1). Measured data on the hearing abilities of cetaceans are sparse, particularly for the larger cetaceans such as the baleen whales. The auditory thresholds of some of the smaller odontocetes

have been determined in captivity. It is generally believed that cetaceans should at least be sensitive to the frequencies of their own vocalizations. Comparisons of the anatomy of cetacean inner ears and models of the structural properties and the response to vibrations of the ear's components in different species provide an indication of likely sensitivity to various sound frequencies. The ears of small toothed whales are optimized for receiving high-frequency sound, while baleen whale inner ears are best in low to infrasonic frequencies (Ketten 1992; 1997; 1998).

Baleen whale vocalizations are composed primarily of frequencies below 1 kHz, and some contain fundamental frequencies as low as 16 Hz (Watkins et al. 1987; Richardson et al. 1995; Rivers 1997; Moore et al. 1998; Stafford et al. 1999; Wartzok and Ketten, 1999) but can be as high as 24 kHz (humpback whale; Au et al. 2006). Clark and Ellison (2004) suggested that baleen whales use low frequency sounds not only for long-range communication, but also as a simple form of echo ranging, using echoes to navigate and orient relative to physical features of the ocean. Information on auditory function in mysticetes is extremely lacking. Sensitivity to low-frequency sound by baleen whales has been inferred from observed vocalization frequencies, observed reactions to playback of sounds, and anatomical analyses of the auditory system. Although there is apparently much variation, the source levels of most baleen whale vocalizations lie in the range of 150-190 dB re 1 µPa at 1 m. Low-frequency vocalizations made by baleen whales and their corresponding auditory anatomy suggest that they have good low-frequency hearing (Ketten 2000), although specific data on sensitivity, frequency or intensity discrimination, or localization abilities are lacking. Marine mammals, like all mammals, have typical U-shaped audiograms that begin with relatively low sensitivity (high threshold) at some specified low frequency with increased sensitivity (low threshold) to a species specific optimum followed by a generally steep rise at higher frequencies (high threshold) (Fay 1988).

The majority of blue and fin whales vocalizations are less than 222 Hz (Cummings and Thompson 1971; Thompson et al. 1992; Berchok et al. 2006; Mellinger and Clarke 2003; Clarke 2004; Rankin et al. 2004). Blue whales produce a variety of low-frequency sounds in a 10-100 Hz band (Cummings and Thompson 1971; Edds 1982; Thompson and Friedl 1982; Alling and Payne 1991; McDonald et al. 1995; Clark and Fristrup 1997; Rivers 1997; Stafford et al. 1998; Stafford et al. 1999; McDonald et al. 2001). Off California, the most typical blue whale signals are very long, patterned sequences of tonal infrasonic sounds in the 15-100 Hz range (Aburto et al. 1997; McDonald et al. 2001; Oleson et al. 2007), and are typically infrequently produced by a small subset of males (Calambokidis et al. 2004; Oleson et al. 2007).

Fin whales produce a variety of low frequency sounds, primarily in the 15-200 Hz band (Watkins 1981; Watkins et al. 1987; Edds 1988; Thompson et al. 1992; McDonald and Fox 1999). The most typical signals are long, patterned sequences of short duration (0.5-2 seconds) infrasonic pulses in the 18-35 Hz range (Patterson and Hamilton 1964; Watkins et al. 1987).

Three sounds are produced by humpback whales: "songs" produced in late fall, winter, and spring by single animals; sounds produced by groups of humpback whales (possibly associated with aggressive behavior among males) on the winter breeding grounds; and sounds produced on the summer feeding grounds. Dominant frequencies of these songs range from 40 Hz to 4 kHz, with components of up to 8 kHz (Thompson et al. 1979; Richardson et al. 1995) and harmonics of the frequency fundamental measured up to 24 kHz (Au et al. 2001, 2006). Source levels average 155 dB re 1 µPa at 1 m and range from 144 to 174 dB re 1 µPa at 1 m (Thompson et al. 1979; Au et al. 2006). Sounds often associated with possible aggressive behavior by males are

quite different from songs, extending from 50 Hz to 10 kHz (or higher), with most energy in components below 3 kHz (Tyack and Whitehead 1983). Sounds are produced less frequently on summer feeding grounds and are at approximately 20-2000 Hz, with median durations of 0.2-0.8 sec and source levels of 175-192 dB re 1 µPa at 1 m (Thompson et al. 1986). Filter-bank models of the humpback whale's ear have been developed from anatomical features of the humpback's ear and optimization techniques (Houser et al. 2001a). The results suggest that humpbacks are sensitive to frequencies between 700 Hz and 10 kHz, but best sensitivity is likely to occur between 2 and 6 kHz.

Minke whales produce a variety of sounds, primarily in the 80-5,000 Hz range. In the Northern Hemisphere, sounds recorded include grunts, thumps, and ratchets from 80-850 Hz and pings and clicks from 3-20 kHz (Winn and Perkins 1976; Thompson et al. 1979; Stewart and Leatherwood 1985; Mellinger et al. 2000; Rankin and Barlow 2003).

The toothed whales produce a wide variety of sounds, which include species-specific broadband "clicks" with peak energy between 10 and 200 kHz, individually variable "burst pulse" click trains, and constant frequency or frequency-modulated (FM) whistles ranging from 4 to 16 kHz (Wartzok and Ketten 1999). The general consensus is that the tonal vocalizations (whistles) produced by toothed whales play an important role in maintaining contact between dispersed individuals, while broadband clicks are used during echolocation (Wartzok and Ketten 1999). Burst pulses have also been strongly implicated in communication, with some scientists suggesting that they play an important role in agonistic encounters (McCowan and Reiss 1995), while others have proposed that they represent "emotive" signals in a broader sense, possibly representing graded communication signals (Herzing 1996). Sperm whales, however, are known to produce only clicks, which are used for both communication and echolocation (Whitehead 2003). Most of the energy of toothed whales social vocalizations is concentrated near 10 kHz, with source levels for whistles as high as 100-180 dB re 1 µPa at 1 m (Richardson et al. 1995). No odontocete has been shown audiometrically to have acute hearing (<80 dB re 1 µPa) below 500 Hz (DoN 2001). Sperm whales produce clicks, which may be used to echolocate (Mullins et al. 1988), with a frequency range from less than 100 Hz to 30 kHz and source levels up to 230 dB re 1 µPa 1 m or greater (Møhl et al. 2000).

Southall et al (2007) has provided a comprehensive review of marine mammal acoustics including designating functional hearing groups. Table 4-1 presents the functional hearing groups and representative species or taxonomic groups for each although most species found in the NWTRC fall in the first two groups, low frequency cetaceans (baleen whales) and mid frequency cetaceans (odontocetes).

General reviews of cetacean and pinniped sound production and hearing may be found in Richardson et al. (1995), Edds-Walton (1997), Wartzok and Ketten (1999), and Au et al. (2000), May-Collado et al. (2007). For a discussion of acoustic concepts, terminology, and measurement procedures, as well as underwater sound propagation, Urick (1983) and Richardson et al. (1995) are recommended.

Table 4-1. Summary of the Five Functional Hearing Groups of Marine Mammals (Based on Southall et al. 2007)

Functional Hearing Group	Estimated Auditory Bandwidth	Species or Taxonomic Groups
Low Frequency Cetaceans (Mysticetes–Baleen whales)	7 Hz to 22 kHz (best hearing is generally below 1000 Hz, higher frequencies result from humpback whales)	All baleen whales
Mid/High Frequency Cetaceans (Odontocetes)	150 Hz to 160 kHz (best hearing is from approximately 10-120 kHz)	Most delphinid species including rough-toothed, bottlenose, spinner, common, Fraser's, dusky, hourglass, Peale, white-beaked and white-sided, Risso's and right whale dolphins; medium and large odontocete whales including melon-headed pygmy killer, false killer, killer whale, pilot sperm whale, beluga whale, narwhal and beaked whales
High-frequency cetaceans (Odontocetes)	200 Hz to 180 kHz (best hearing is from approximately 10-150 kHz)	Porpoise species including the harbor, finless, and Dall's porpoise; river dolphins including the Baiji, Ganges, Amazon river dolphins; the dwarf and pygmy sperm whales), and Commerson's, Heaviside and Hector's dolphins
Pinnipeds in water	75 Hz to 75 kHz (best hearing is from approximately 1-30 kHz)	All seals, fur seals, sea lions and walrus
Pinnipeds in air	75 Hz to 30 kHz (best hearing is from approximately 1-16 kHz)	All seals, fur seals, sea lions and walrus

4.2 ESA-Listed Marine Mammal Species in the Action Area

There are nine marine mammal species within the marine waters of California, Oregon, and Washington listed as endangered or threatened under the Endangered Species Act (ESA) with confirmed or possible occurrence in the NWTRC. These include the blue whale, fin whale, humpback whale, North Pacific right whale, sei whale, sperm whale, Southern resident killer whale, Steller sea lion, and southern sea otter. Information on density estimates and dive depth distribution provided for each species are used in the acoustic exposure analysis.

4.2.1 Blue whale (*Balaenoptera musculus*)

Stock. Eastern North Pacific

Listing Status. In the North Pacific, the International Whaling Commision (IWC) began management of commercial whaling for blue whales in 1969; blue whales were fully protected from commercial whaling in 1976 (Allen 1980). Blue whales were listed as endangered under the ESA in 1970 and a recovery plan has been prepared (NMFS 1998). They are also protected by the Convention on International Trade in Endangered Species of wild flora and fauna and the Marine Mammal Protection Act of 1972. Blue whales are listed as endangered on the World Conservation Union (IUCN) Red List of Threatened Animals (Baillie and Groombridge 1996). Critical habitat has not been designated for blue whales.

Population Status- The blue whale was severely depleted by commercial whaling in the twentieth century (NMFS 1998). In the North Pacific, pre-exploitation population size is speculated to be approximately 4,900 blue whales (Wade and Gerrodette 1993). Blue whale population structure in the North Pacific remains uncertain, but two stocks are recognized within U.S. waters: the Hawaiian and the eastern North Pacific (NMFS 2006e). There is no clear information on the population trend of blue whales off California. The abundance estimate for this stock of blue whales is 1,186 (Coefficient of Variation [CV] =0.19) individuals (Carretta et al 2007).

A clear population trend for blue whales is difficult to detect under current survey methods. An increasing trend between 1979/80 and 1991 and between 1991 and 1996 was suggested by available survey data, but it was not statistically significant (Carretta et al. 2006). The abundance of blue whales along the California coast has clearly been increasing during the past two decades (Calambokidis et al. 1990; Barlow 1994; Calambokidis 1995). The magnitude of this increase is considered too large to be explained by population growth alone, and it is therefore assumed that a shift in distribution may have occurred (NMFS 1998). However, the scarcity of blue whales in areas of former abundance (e.g., Gulf of Alaska near the Aleutian Islands) suggests that the increasing trend does not apply to the species' entire range in the eastern North Pacific (Calambokidis et al. 1990). Although the population in the North Pacific is expected to have grown since being given protected status in 1966, the possibility of continued unauthorized takes by Soviet whaling vessels after blue whales were protected in 1966 (Yablokov 1994) and the existence of incidental ship strikes and gillnet mortality makes this uncertain.

Distribution—The blue whale has a worldwide distribution in circumpolar and temperate waters. Blue whales undertake seasonal migrations and were historically hunted on their summer, feeding areas. It is assumed that blue whale distribution is governed largely by food requirements and that populations are seasonally migratory. Poleward movements in spring allow the whales to take advantage of high zooplankton production in summer. Movement toward the subtropics in the fall allows blue whales to reduce their energy expenditure while fasting, avoid ice entrapment in some areas, and engage in reproductive activities in warmer waters of lower latitudes. For example, blue whales were taken off the west coast of Baja California as early as the mid-19th century (Scammon 1874). The timing varied, but whalers located few blue whales in wintering areas from December to February. Observations made after whaling was banned revealed a similar pattern: blue whales spend most of the summer foraging at higher latitudes where the waters are more productive (Sears 1990; Calambokidis et al. 1990; Calambokidis 1995).

The eastern North Pacific stock feeds in waters from California to Alaska in summer and fall, and migrates south to waters from Mexico to Costa Rica in winter (NMFS 2006e). Blue whales are known to feed in the southern part of the Pacific Northwest Operating Area (OPAREA). During the spring and early summer, the blue whales are typically located south of 44°N, from the shore to seaward of the OPAREA boundary. Based on whaling records off British Columbia, additional whales are found north of 48°N,. Occurences of blue whales between 44°N and 48°N during the spring is not as common. Waters within the NWTRC presumably are used as a feeding area. Year-round, the Puget Sound is an area of rare occurrence for the blue whale.

From late summer into autumn, the coast of the Pacific Northwest OPAREA is an area of high occurrence for the blue whale. Blue whales are feeding in the area as late as October, although fewer individuals are seen because the majority of the population migrates south. Acoustic data collected by Sound Surveillance System hydrophones reveal that males are calling at this time of

the year in this area (Stafford et al. 2001). Based on predictive spatial habitat models, the density of blue whales in the NWTRC is estimated to be 0.0005 individuals per square km (DoN 2007a, Appendix B).

Life History—The eastern North Pacific stock feeds in waters from California to Alaska in summer and fall, migrates south to the waters of Mexico to Costa Rica in winter (NMFS 2006e) for breeding and to give birth (Mate et al.1999).

Diving Behavior—Blue whales spend more than 94 percent of their time below the water's surface (Lagerquist et al. 2000). Croll et al. (2001) determined that blue whales dived to an average of 462 ft (141 m) and for 7.8 minutes (min) when foraging and to 222 ft (68 m) and for 4.9 min when not foraging. Data from southern California and Mexico showed that whales dived to >328 ft (100 m) for foraging; once at depth, vertical lunge-feeding often occurred (lunging after prey). Lunge-feeding at depth is energetically expensive and likely limits the deeper diving capability of blue whales. Foraging dives are deeper than traveling dives; traveling dives were generally to ~ 100 ft (30 m). Typical dive shape is somewhat V-shaped, although the bottom of the V is wide to account for the vertical lunges at bottom of dive. Blue whales also have shallower foraging dives. Calambokidis et al. (2003) deployed tags on blue whales and collected data on dives as deep as about 984 ft . Lunge-feeding at depth is energetically expensive and likely limits the deeper diving capability of blue whales. Foraging dives are deeper than traveling dives; traveling dives were generally to ~ 100 ft (30 m). Typical dive shape is somewhat V-shaped, although the bottom of the V is wide to account for the vertical lunges at bottom of dive. Blue whales also have shallower foraging dives. Best information for percentage of time at depth is from Lagerquist et al (2000) collected on blue whales off central California: 78% in 0 – 52 ft (0-16 m), 9% in 53 – 105 ft (17-32 m), 13% in > 105 ft (32 m).

Acoustics—Blue produce calls with the lowest frequency and highest source levels of all cetaceans.). Blue whale vocalizations are long, patterned low-frequency sounds with durations up to 36 sec (Richardson et al. 1995) repeated every 1 to 2 min (Mellinger and Clark 2003). The frequency range of their vocalizations is 12 to 400 hertz (Hz), with dominant energy in the infrasonic range at 12 to 25 Hz (Ketten 1998; Mellinger and Clark 2003). Source levels are up to 188 decibels (dB) re 1 µPa-m (Ketten 1998; McDonald et al, 2001). During the Magellan II Sea Test (at-sea exercises designed to test systems for antisubmarine warfare), off the coast of California in 1994, blue whale vocalization source levels at 17 Hz were estimated in the range of 195 dB re 1 µPa-m (Aburto et al. 1997). Širović et al. (2007) reported that blue whales produced vocalizations with a source level of 189 ± 3 dB re:1 Pa-1 m over a range of 25–29 Hz and could be detected up to 200 km away. A comparison of recordings between November 2003 and November 1964 and 1965 reveals a strong blue whale presence near San Nicolas Island (McDonald et al. 2006). A long-term shift in the frequency of the blue whale calling is seen; in 2003 the spectral energy peak was 16 Hz, whereas in 1964-65 the energy peak was near 22.5 Hz, illustrating a more than 30% shift in call frequency over four decades (McDonald et al. 2006).

Vocalizations of blue whales appear to vary among geographic areas (Rivers 1997), with clear differences in call structure suggestive of separate populations for the western and eastern regions of the North Pacific (Stafford et al. 2001). Stafford et al. (2005) recorded the highest calling rates when blue whale prey was closest to the surface during its vertical migration. Wiggins et al. (2005) reported the same trend of reduced vocalization during daytime foraging and then an increase in vocalizations at dusk as prey move up into the water column and disperse. Blue whales make seasonal migrations to areas of high productivity to feed and

vocalize less in the feeding grounds than during the migration (Burtenshaw et al. 2004). Oleson et al. (2007) reported higher calling rates in shallow diving (< 100 ft [30 m]) whales while deeper diving whales (> 165 ft [50 m]) were likely feeding and calling less.

As with other mysticete sounds, the function of vocalizations produced by blue whales is unknown. Hypothesized functions include: (1) maintenance of inter-individual distance, (2) species and individual recognition, (3) contextual information transmission (e.g., feeding, alarm, courtship), (4) maintenance of social organization (e.g., contact calls between females and offspring), (5) location of topographic features, and (6) location of prey resources (Thompson et al. 1992). Responses to conspecific sounds have been demonstrated in a number of mysticetes (Edds-Walton 1997), and there is no reason to believe that blue whales do not communicate similarly. While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing. Although no recent studies have directly measured the sound sensitivity in blue whales, we assume that blue whales are able to receive sound signals in roughly the same frequencies as the signals they produce.

Impacts of human activity—Historic Whaling- Blue whales were occasionally hunted by the sailing-vessel whalers of the 19th century (Scammon 1874). The introduction of steam power in the second half of that century made it possible for boats to overtake large, fast-swimming blue whales and other rorquals. From the turn of the century until the mid-1960s, blue whales from various stocks were intensely hunted in all the world's oceans. Blue whales were protected in portions of the Southern Hemisphere beginning in 1939, but were not fully protected in the Antarctic until 1965. In 1955, they were given complete protection in the North Atlantic under the International Convention for the Regulation of Whaling; this protection was extended to the Antarctic in 1965 and the North Pacific in 1966 (Gambell 1979; Best 1993). The protected status of North Atlantic blue whales was not recognized by Iceland until 1960 (Sigurjonsson 1988). Only a few illegal kills of blue whales have been documented in the Northern Hemisphere, including three at Canadian east-coast whaling stations during 1966-69 (Mitchell 1974), some at shore stations in Spain during the late 1950s to early 1970s (Aguilar and Lens 1981; Sanpera and Aguilar 1992), and at least two by "pirate" whalers in the eastern North Atlantic in 1978 (Best 1992). Some illegal whaling by the USSR also occurred in the North Pacific (Yablokov 1994); it is likely that blue whales were among the species taken by these activities, but the extent of the catches is not known. Since gaining complete legal protection from commercial whaling in 1966, some populations have shown signs of recovery, while others have not been adequately monitored to determine their status (NMFS 1998). Removal of this significant threat has allowed increased recruitment in the population, and therefore, the blue whale population in the eastern North Pacific is expected to have grown.

Fisheries Interactions—Because little evidence of entanglement in fishing gear exists, and large whales such as the blue whale may often die later and drift far enough not to strand on land after such incidents, it is difficult to estimate the numbers of blue whales killed and injured by gear entanglements. In addition, the injury or mortality of large whales due to interactions or entanglements in fisheries may go unobserved because large whales swim away with a portion of the net or gear. Fishers have reported that large whales tend to swim through their nets without entangling and causing little damage to nets (Barlow et al. 1997).

Ship Strikes-Because little evidence of ship strikes exists, and large whales such as the blue whale may often die later and drift far enough not to strand on land after such incidents, it is difficult to estimate the numbers of blue whales killed and injured by ship strikes. In addition, a

boat owner may be unaware of the strike when it happens. Ship strikes were implicated in the deaths of blue whales in 1980, 1986, 1987, 1993, and 2002 (Carretta et al. 2006). Additional mortality from ship strikes probably goes unreported because the whales do not strand, or if they do, they do not always have obvious signs of trauma (Carretta et al. 2006).

4.2.2 Fin whale (*Balaenoptera physalus*)

Stock – California/Oregon/Washington

Listing—In the North Pacific, the IWC began management of commercial whaling for fin whales in 1969; fin whales were fully protected from commercial whaling in 1976 (Allen 1980). Fin whales were listed as endangered under the ESA in 1970 and a draft recovery plan was prepared (NMFS 2006c). They are also protected by the Convention on International Trade in Endangered Species of wild flora and fauna and the Marine Mammal Protection Act of 1972. Fin whales are listed as endangered on the IUCN Red List of Threatened Animals (Baillie and Groombridge 1996). Critical habitat has not been designated for fin whales.

Population Status—In the North Pacific, the total pre-exploitation population size of fin whales is estimated at 42,000 to 45,000 whales (Ohsumi and Wada 1974). The most recent abundance estimate (early 1970s) for fin whales in the entire North Pacific basin is between 14,620 and 18,630 whales (NMFS 2006e). Fin whales have a worldwide distribution with two distinct stocks recognized in the North Pacific: the East China Sea Stock and "the rest of the North Pacific Stock" (Donovan 1991). Currently, there are considered to be three stocks in the North Pacific for management purposes: an Alaska Stock, a Hawaii Stock, and a California/Oregon/Washington Stock (Barlow et al. 1997). Currently, the best abundance estimate for the California/Oregon/Washington Stock is 3,454 (CV = 0.27) individuals (Barlow and Forney 2007).

During the early 1970s, 8,520 to 10,970 fin whales were surveyed in the eastern half of the North Pacific (Braham 1991). Moore et al. (2000) conducted surveys for whales in the central Bering Sea in 1999 and tentatively estimated the fin whale population was about 4,951 animals (95% C.I. 2,833-8,653). If these historic estimates are statistically reliable, the population size of fin whales has not increased significantly over the past 20 years despite an international ban on whaling in the North Pacific. The strongest contrary evidence comes from investigators conducting seabird surveys around the Pribilof Islands in 1975-1978 and 1987-1989. These investigators observed more fin whales in the second survey and suggested they were more abundant in the survey area (Baretta and Hunt 1994). However, observations of increased counts of fin whales in an area do not support a conclusion that there are more fin whales until changes in distribution have been ruled out first.

Distribution—Fin whales occur in oceans of both Northern and Southern Hemispheres between 20–75° N and S latitudes (NMFS 2006e). Fin whales are distributed widely in the world's oceans. In the northern hemisphere, most migrate seasonally from high Arctic feeding areas in summer to low latitude breeding and calving areas in winter. During the summer in the North Pacific Ocean, fin whales are distributed in the Chukchi Sea, around the Aleutian Islands, the Gulf of Alaska, and along the coast of North America to CaliforniaWorldwide, fin whales were severely depleted by commercial whaling activities. The fin whale is found in continental shelf and oceanic waters (Gregr and Trites 2001; Reeves et al. 2002). Globally, it tends to be aggregated in locations where populations of prey are most plentiful, irrespective of water depth, although those locations may shift seasonally or annually (Payne et al. 1986, 1990; Kenney et al.

1997; Notarbartolo-di-Sciara et al. 2003). Fin whales in the North Pacific spend the summer feeding along the cold eastern boundary currents (Perry et al. 1999).

The North Pacific population summers from the Chukchi Sea to California, and winters from California southward (Gambell 1985). Based on predictive spatial habitat models, density estimates of fin whales in the NWTRC ranged from 0 to 0.0245 individuals per square km, with an overall density estimate of 0.0014 individuals per square km (DoN 2007a, Appendix B). Given the size of the NWTRC, the fin whale population of the NWTRC is estimated at 608 individuals.

Life History—Fin whales become sexually mature between six to ten years of age, depending on density-dependent factors (Gambell 1985b). Reproductive activities for fin whales occur primarily in the winter. Gestation lasts about 12 months and nursing occurs for 6 to 11 months (Perry et al. 1999). The age distribution of fin whales in the North Pacific is unknown. Natural sources and rates of mortality are largely unknown, but Aguilar and Lockyer (1987) suggest annual natural mortality rates may range from 0.04 to 0.06 (based on studies of northeast Atlantic fin whales). The occurrence of the nematode *Crassicauda boopis* appears to increase the potential for kidney failure in fin whales and may be preventing some fin whale stocks from recovering from whaling (Lambertsen 1992, as cited in Perry et al. 1999). Killer whale or shark attacks may result in serious injury or death in very young and sick whales (Perry et al. 1999). NMFS has no records of fin whales being killed or injured by commercial fisheries operating in the North Pacific (Ferrero et al. 2000). Natural sources and rates of mortality are largely unknown, but Aguilar and Lockyer (1987) suggest annual natural mortality rates may range from 0.04 to 0.06 (based on studies of northeast Atlantic fin whales). The occurrence of the nematode. Crassicauda boopis, appears to increase the potential for kidney failure in fin whales and may be preventing some fin whale stocks from recovering from whaling (Lambertsen 1992, as cited in Perry et al. 1999). Killer whale or shark attacks may result in serious injury or death in very young and sick whales (Perry et al. 1999). NMFS has no records of fin whales being killed or injured by commercial fisheries operating in the North Pacific (Ferrero et al. 2000).

Diving Behavior—Fin whales typically dive for 5 to 15 min, separated by sequences of 4 to 5 blows at 10 to 20 sec intervals (Cetacean and Turtle Assessment Program 1982; Stone et al. 1992; Lafortuna et al. 2003). Kopelman and Sadove (1995) found significant differences in blow intervals, dive times, and blows per hour between surface feeding and non-surface-feeding fin whales. Croll et al. (2001) determined that fin whales dived to 321 ft (100 m) (Standard Deviation [SD] = ± 106.8 ft [33 m]) with a duration of 6.3 min (SD = ± 1.53 min) when foraging and to 168 ft (51 m) (SD = ± 97.3 ft [30 m]) with a duration of 4.2 min (SD = ± 1.67 min) when not foraging. Goldbogen et al. (2006) reported that fin whales in California made foraging dives to a maximum of 748-889 ft (228-271 m) and dive durations of 6.2-7.0 min. Fin whale dives exceeding 492 ft (150 m) and coinciding with the diel migration of krill were reported by Panigada et al. (1999). Fin whales feed on planktonic crustaceans, including *Thysanoessa* sp. and *Calanus* sp., as well as schooling fish including herring, capelin and mackerel (Aguilar 2002). Depth distribution data from the Ligurian Sea in the Mediterranean are the most complete (Panigada et al. 2003), and showed differences between day and night diving; daytime dives were shallower (< 328 ft [100 m]) and night dives were deeper (> 1,312 ft [400m]), likely taking advantage of nocturnal prey migrations into shallower depths; this data may be atypical of fin whales elsewhere in areas where they do not feed on vertically-migrating prey.

Goldbogen et al. (2006) studied fin whales in southern California and found that 60% of total time was spent diving, with the other 40% near surface (< 164 ft [50m]); dives were to > 738 ft (225 m) and were characterized by rapid gliding ascent, foraging lunges near the bottom of dive, and rapid ascent with flukes. Dives were somewhat V-shaped although the bottom of the V is wide. Based on information from Goldbogen et al. (2006), percentage of time at depth levels is estimated as 44% at < 164 ft (50 m), 23% at 164-723 ft (50-225 m) (covering the ascent and descent times) and 33% at > 723 ft (225 m).

Acoustics—Underwater sounds produced by fin whales are one of the most studied Balaenoptera sounds. Infrasonic (10-200 Hz), pattern sounds have been documented for fin whales (Watkins et al. 1987; Clark and Fristrup 1997; McDonald and Fox 1999). Charif et al. (2002) estimated source levels between 159-184 dB re:1 µPa-1 m for fin whales vocalizations recorded between Oregon and Northern California. Fin whales can also produce a variety of sounds with a frequency range up to 750 Hz. The long, patterned 15 to 30 Hz vocal sequence is most typically recorded; only males are known to produce these (Croll et al. 2002). The most typical signals are long, patterned infrasonic sequences of short duration (0.5-2s) in the 18-35 Hz range (Patterson and Hamilton 1964). Estimated source levels are as high as 190 dB (Patterson and Hamilton 1964; Watkins et al. 1987a; Thompson et al. 1992; McDonald et al. 1995). Širović et al. (2007) reported that fin whales produced vocalizations with a source level of 189 ± 4 dB re:1 Pa-1 m over a range of 15–28 Hz and could be detected up to 56 km away. In temperate waters intense bouts of long patterned sounds are very common from fall through spring, but also occur to a lesser extent during the summer in high latitude feeding areas (Clark and Charif 1998). Short sequences of rapid pulses in the 20-70 Hz band are associated with animals in social groups (McDonald et al. 1995; Clark pers. comm.; McDonald pers. comm.). Each pulse lasts on the order of one second and contains twenty cycles (Tyack 1999). Particularly in the breeding season, fin whales produce series of pulses in a regularly repeating pattern. These bouts of pulsing may last for longer than one day (Tyack 1999). The seasonality and stereotype of the bouts of patterned sounds suggest that these sounds are male reproductive displays (Watkins et al. 1987a), while the individual counter-calling data of McDonald et al. (1995) suggest that the more variable calls are contact calls. Some authors feel there are geographic differences in the frequency, duration and repetition of the pulses (Thompson et al. 1992). As with other mysticete sounds, the function of vocalizations produced by fin whales is unknown. Hypothesized functions include: (1) maintenance of inter-individual distance, (2) species and individual recognition, (3) contextual information transmission (e.g., feeding, alarm, courtship), (4) maintenance of social organization (e.g., contact calls between females and offspring), (5) location of topographic features, and (6) location of prey resources (review by Thompson et al. 1992). Responses to conspecific sounds have been demonstrated in a number of mysticetes, and there is no reason to believe that fin whales do not communicate similarly (Edds-Walton 1997). The low-frequency sounds produced by fin whales have the potential to travel over long distances, and it is possible that long-distance communication occurs in fin whales (Payne and Webb 1971; Edds-Walton 1997). Also, there is speculation that the sounds may function for long-range echolocation of large-scale geographic targets such as seamounts, which might be used for orientation and navigation (Tyack 1999).

The most typical fin whale sound is a 20 Hz infrasonic pulse (actually an FM sweep from about 23 to 18 Hz) with durations of about 1 sec and can reach source levels of 184 to 186 dB re 1 µPa-m (maximum up to 200) (Richardson et al. 1995; Charif et al. 2002). Croll et al. (2002) suggested that these long, patterned vocalizations might function as male breeding displays,

much like those that male humpback whales sing. The source depth, or depth of calling fin whales, has been reported to be about 162 ft (50 m) (Watkins et al. 1987).

Although no studies have directly measured the hearing sensitivity of fin whales, we assume that fin whales are able to receive sound signals in roughly the same frequencies as the signals they produce. This suggests fin whales, like other baleen whales are more likely to have their best hearing capacities at low frequencies, including infrasonic frequencies, rather than at mid- to high-frequencies (Ketten 1997).

Impacts of human activity—As early as the mid-seventeenth century, the Japanese were capturing fin, blue, and other large whales using a fairly primitive open-water netting technique (Tønnessen and Johnsen 1982, Cherfas 1989). In 1864, explosive harpoons and steam-powered catcher boats were introduced in Norway, allowing the large-scale exploitation of previously unobtainable whale species. The North Pacific and Antarctic whaling operations soon added this >modern' equipment to their arsenal. After blue whales were depleted in most areas, the smaller fin whale became the focus of whaling operations and more than 700,000 fin whales were landed in the twentieth century. The incidental take of fin whales in fisheries is extremely rare. In the California/Oregon drift gillnet fishery, observers recorded the entanglement and mortality of one fin whale, in 1999, off southern California (NMFS 2000). Based on a worst-case scenario, NMFS estimates that a maximum of six fin whales (based on calculations that adjusted the fin whale observed entangled and killed in 1999 by the number of sets per year) in a given year could be captured by the California-Oregon drift gillnet fleet and killed (NMFS 2000). Anecdotal observations from fishermen, suggest that large whales swim through their nets rather than get caught in them (NMFS 2000). Because of their size and strength, fin whales probably swim through fishing nets which might explain why these whales are rarely reported as having become entangled in fishing gear.

4.2.3 Humpback whale (*Megaptera novaeangliae*)

Stock – Eastern North Pacific

Listing Status—The IWC first protected humpback whales in the North Pacific in 1966. They are also protected under CITES. In the U.S., humpback whales were listed as endangered under the ESA in 1970 and a recovery plan has been prepared (NMFS 1991). Critical habitat has not been designated for this species in waters off California, Oregon, and Washington.

Population Status—Humpback whales live in all major ocean basins from equatorial to sub-polar latitudes migrating from tropical breeding areas to polar or sub-polar feeding areas (Jefferson et al. 1993, NMFS 2006e). Three Pacific stocks of humpback whales are recognized in the Pacific Ocean and include the Western North Pacific stock, Central North Pacific stock, and Eastern North Pacific stock Calambokidis et al. 1997; Baker et al. 1998). The eastern North Pacific humpback whale stock is the one most likely to be encountered within the NWTRC. In the entire North Pacific ocean prior to 1905, it is estimated that there were 15,000 humpback whales basin-wide (Rice 1978). In 1966, after heavy commercial exploitation, humpback abundance was estimated at 1,000 to 1,200 whales (Rice 1978), although it is unclear if estimates were for the entire North Pacific or just the eastern North Pacific. The best abundance estimate for the Eastern North Pacific Stock, is 1,396 (CV = 0.15) individuals (Carretta et al. 2007).

Distribution—The Eastern North Pacific Stock inhabits waters from Costa Rica (Steiger et al. 1991) to southern British Columbia (Calambokidis et al. 1993). This stock is most abundant in

coastal waters off California during spring and summer, and off Mexico during autumn and winter. Although humpback whales typically travel over deep, oceanic waters during migration, their feeding and breeding habitats are mostly in shallow, coastal waters over continental shelves (Clapham and Mead 1999). Shallow banks or ledges with high sea-floor relief characterize feeding grounds (Payne et al. 1990; Hamazaki 2002). North Pacific humpback whales are distributed generally in four distinct wintering areas: the Ryukyu and Ogasawara (Bonin) Islands (south of Japan), Hawai'i, the Revillagigedo Islands off Mexico, and along the coast of mainland Mexico (Calambokidis et al. 2001). There is known to be some interchange of whales among different wintering grounds, and some matches between Hawaii and Japan, and between Hawaii and Mexico have been found (Salden et al. 1999; Calambokidis et al. 2000; 2001). During summer months, North Pacific humpback whales feed in a nearly continuous band from southern California to the Aleutian Islands, Kamchatka Peninsula, and the Bering and Chukchi seas (Calambokidis et al. 2001).

Although humpback whales were common in inland Washington waters prior to the whaling period, only a few sightings have been made in this area since then (Scheffer and Slipp 1948; Calambokidis and Steiger 1990; Pinnell and Sandilands 2004). Today, humpback whales occasionally occur in the Puget Sound but do not remain for long (Everitt et al. 1980; Osborne and Ransom 1988). Based on historical whaling records, an area of humpback whale occurrence was located in the Strait of Juan de Fuca, in the central part of the Puget Sound (around San Juan Island and west side of Whidbey Island), and near Nanaimo (west coast of the Strait of Georgia)**.** Occurrences were rare beyond this area.

Based on predictive spatial habitat models, density estimates of humpback whales in the NWTRC ranged from 0 to 0.062 individuals per square km, with an overall density estimate of 0.0007 individuals per square km (DoN 2007a, Appendix B).

Life History—Humpbacks primarily feed on small schooling fish and krill (Caldwell and Caldwell 1983). The whales primarily feed along the shelf break and continental slope (Green et al. 1992; Tynan et al. 2005). Off Washington, they concentrate between Juan de Fuca Canyon and the outer edge of the shelf break in a region called "the Prairie," near Barkley and Nitnat Canyons, and near Swiftsure Bank (Calambokidis et al. 2004b). Off the coast of Oregon, humpbacks congregate near Heceta Bank (Green et al. 1992). These locations represent important feeding areas for humpback whales in the OPAREA. Humpback whales migrate south from California to the waters off Mexico and Costa Rica to breed and to give birth (Calambokidis et al. 2004).

Diving Behavior—Humpback whale diving behavior depends on the time of year (Clapham and Mead 1999). In summer, most dives last less than 5 min; those exceeding 10 min are atypical. In winter (December through March), dives average 10 to 15 min; dives of greater than 30 min have been recorded (Clapham and Mead 1999). Although humpback whales have been recorded to dive as deep as about 1,638 ft (500 m) (Dietz et al. 2002), on the feeding grounds they spend the majority of their time in the upper 400 ft (122 m) of the water column (Dolphin 1987; Dietz et al. 2002). Humpback whales on the wintering grounds do dive deeply; Baird et al. (2000) recorded dives to 577 ft (176 m).

Like other large mysticetes, they are a "lunge feeder" taking advantage of dense prey patches and engulfing as much food as possible in a single gulp. They also blow nets, or curtains, of bubbles around or below prey patches to concentrate the prey in one area, then lunge with mouths open

through the middle. Dives appear to be closely correlated with the depths of prey patches, which vary from location to location. In the North Pacific, most dives were of fairly short duration (<4 min) with the deepest dive to 485 ft (148 m) (southeast Alaska; Dolphin 1987), while whales observed feeding on Stellwagen Bank in the North Atlantic dove to < 131 ft (40 m) (Hain et al. 1995). Depth distribution data collected at a feeding area in Greenland resulted in the following best estimation of depth distribution: 37% of time at < 13 ft (4 m), 25% at 14-66 ft (4-20 m), 7% at 67-115 ft (21-35 m), 4% at 116-164 ft (36-50 m), 6% at 165-328 ft (51-100 m), 7% at 166-492 ft (101-150 m), 8% at 167-656 ft (151-200 m), 6% at 657-984 ft (201-300 m), and <1% at > 984 ft (300 m) (Dietz et al. 2002).

Acoustics—Humpback whales are known to produce three classes of vocalizations: (1) "songs" in the late fall, winter, and spring by solitary males; (2) sounds made within groups on the wintering (calving) grounds; and (3) social sounds made on the feeding grounds (Richardson et al. 1995). The best-known types of sounds produced by humpback whales are songs, which are thought to be breeding displays used only by adult males (Helweg et al. 1992). Singing is most common on breeding grounds during the winter and spring months, but is occasionally heard outside breeding areas and out of season (Matilla et al. 1987; Clark and Clapham 2004). There is geographical variation in humpback whale song, with different populations singing different songs, and all members of a population using the same basic song. However, the song evolves over the course of a breeding season, but remains nearly unchanged from the end of one season to the start of the next (Payne et al. 1983). Social calls are from 50 Hz to over 10 kHz, with the highest energy below 3 kHz (Silber 1986). Female vocalizations appear to be simple; Simão and Moreira (2005) noted little complexity. The male song, however, is complex and changes between seasons. Components of the song range from under 20 Hz to 4 kHz and occasionally 8 kHz, with source levels of 144 to 174 dB re 1 µPa m, with a mean of 155 dB re 1 µPa-m (Thompson et al. 1979; Payne and Payne 1985, Frazer and Mercado 2000). Au et al. (2001) recorded high-frequency harmonics (out to 13.5 kHz) and source level (between 171 and 189 dB re 1 µPa-m) of humpback whale songs. Au et al. (2006) took recordings of whales off Hawaii and found high frequency harmonics of songs extending beyond 24 kHz, which may indicate that they can hear at least as high as this frequency. Songs have also been recorded on feeding grounds (Mattila et al. 1987; Clark and Clapham 2004). "Feeding calls," unlike song and social sounds are highly stereotyped series of narrow-band trumpeting calls. They are 20 Hz to 2 kHz, less than 1 second in duration, and have source levels of 175 to 192 dB re 1 µPa-m (U.S. Navy 2006a).

The main energy of humpback whale songs lies between 0.2 and 3.0 kHz, with frequency peaks at 4.7 kHz. Feeding calls, unlike song and social sounds, are highly stereotyped series of narrow-band trumpeting calls. They are 20 Hz to 2 kHz, less than 1 sec in duration, and have source levels of 175 to 192 dB re 1 µPa-m. The fundamental frequency of feeding calls is approximately 500 Hz (D'Vincent et al. 1985).

No tests on humpback whale hearing have been made. Houser et al. (2001) constructed a humpback audiogram using a mathematical model based on the internal structure of the ear. The predicted audiogram indicates sensitivity to frequencies from 700 Hz to 10 kHz, with maximum relative sensitivity between 2 and 6 kHz. Recent information on the songs of humpback whales suggests that their hearing, if animals hear the sounds they make, may extend to frequencies of at least 24 kHz (Au et al. 2006). Maybaum (1989) reported that humpback whales showed a mild response to a hand held sonar marine mammal detection and location device (frequency of 3.3

kHz at 219 dB re 1µPa @ 1 meter or frequency sweep of 3.1-3.6 kHz) although this system is significantly different from the Navy's hull mounted sonars. In addition, the system had some low frequency components (below 1 kHz) which may be an artifact of the acoustic equipment. This may have affected the response of the whales to both the control and sonar playbacks.

Impacts of human activity- Historic whaling—Commercial whaling, the single most significant impact on humpback whales ceased in the North Atlantic in 1955 and in all other oceans in 1966. The humpback whale was the most heavily exploited by Soviet whaling fleets after World War II.

Fisheries Interactions-Entanglement in fishing gear poses a threat to individual humpback whales throughout the Pacific. Reports of entangled humpbacks whales found swimming, floating, or stranded with fishing gear attached, have been documented in the North Pacific. A number of fisheries based out of west coasts ports may incidentally take the ENP stock of humpback whale, and documented interactions are summarized in the U.S. Pacific Marine Mammal Stock Assessments: 2006 (Carretta et al. 2007). The estimated impact of fisheries on the ENP humpback whale stock is likely underestimated, since the serious injury or mortality of large whales due to entanglement in gear, may go unobserved because whales swim away with a portion of the net, line, buoys, or pots. According to Carretta et al. (2007) and the California Marine Mammal Stranding Network Database (U.S Department of Commerce 2006), 12 humpback whales and two unidentified whales have been reported as entangled in fishing gear (all crab pot gear, except for one of the unidentified whales) since 1997.

Ship Strikes-Humpback whales, especially calves and juveniles, are highly vulnerable to ship strikes and other interactions with non-fishing vessels. Younger whales spend more time at the surface, are less visible, and closer to shore (Herman et al. 1980; Mobley et al. 1999), thereby making them more susceptible to collisions. Humpback whale distribution overlaps significantly with the transit routes of large commercial vessels, including cruise ships, large tug and barge transport vessels, and oil tankers.

Ship strikes were implicated in the deaths of at least two humpback whales in 1993, one in 1995, and one in 2000 (Carretta et al. 2006). During 1999-2003, there were an additional 5 injuries and two mortalities of unidentified whales, attributed to ship strikes. Additional mortality from ship strikes probably goes unreported because the whales do not strand or, if they do, they do not have obvious signs of trauma. Several humpback whales have been photographed in California with large gashes in their dorsal surface that appear to be from ship strikes (Carretta et al. 2006).

Whale watching boats and boats from which scientific research is being conducted specifically direct their activities toward whales and may have direct or indirect impacts on humpback whales. The growth of the whale-watching industry has not increased as rapidly for the ENP stock of humpback whales, as it has for the central North Pacific stock (wintering grounds in Hawaii and summering grounds in Alaska), but whale-watching activities do occur throughout the ENP stock's range. There is concern regarding the impacts of close vessel approaches to large whales, since harassment may occur, preferred habitats may be abandoned, and fitness and survivability may be compromised if disturbance levels are too high. While a 1996 study in Hawaii measured the acoustic noise of different whale-watching boats (Au and Green 2000) and determined that the sound levels were unlikely to produce grave effects on the humpback whale auditory system, the potential direct and indirect effects of harassment due to vessels cannot be discounted. Several investigators have suggested shipping noise may have caused humpback

whales to avoid or leave feeding or nursery areas (Jurasz and Jurasz 1979; Dean et al. 1985), while others have suggested that humpback whales may become habituated to vessel traffic and its associated noise. Still other researchers suggest that humpback whales may become more vulnerable to vessel strikes once they habituate to vessel traffic (Swingle et al. 1993; Wiley et al. 1995).

Other Threats-Similar to fin whales, humpbacks are potentially affected by a resumption of commercial whaling, loss of habitat, loss of prey (for a variety of reasons including climate variability), underwater noise, and pollutants. Generally, very little is known about the effects of organochlorine pesticides, heavy metals, and PCB's and other toxins in baleen whales, although the impacts may be less than higher trophic level odontocetes due to baleen whales' lower levels of bioaccumulation from prey.

Anthropogenic noise may also affect humpback whales, as humpback whales seem to respond to moving sound sources, such as whale-watching vessels, fishing vessels, recreational vessels, and low-flying aircraft (Beach and Weinrich 1989; Clapham et al. 1993; Atkins and Swartz 1989). Their responses to noise are variable and have been correlated with the size, composition, and behavior of the whales when the noises occurred (Herman et al. 1980; Watkins et al. 1981; Krieger and Wing 1986).

4.2.4 Sei whale (*Balaenoptera borealis*)

Stock - Eastern North Pacific

Listing Status—Sei whales did not have meaningful protection at the international level until 1970, when catch quotas for the North Pacific began to be set on a species basis (rather than on the basis of total production, with six sei whales considered equivalent to one "blue whale unit"). Prior to that time, the kill was limited only to the extent that whalers hunted selectively for the larger species with greater return on effort (Allen 1980). The sei whale was given complete protection from commercial whaling in the North Pacific in 1976. In the late 1970's, some "pirate" whaling for sei whales took place in the eastern North Atlantic (Best 1992). There is no direct evidence of illegal whaling for this species in the North Pacific although the acknowledged misreporting of whaling data by Soviet authorities (Yablokov 1994) means that catch data are not wholly reliable. It is also classified as "endangered" by the IUCN (Baillie and Groombridge 1996) and is listed in CITES Appendix I. Critical habitat has not been designated for this species for the eastern North Pacific stock.

Population Status—The IWC groups all of sei whales in the entire North Pacific Ocean into one stock (Donovan 1991). However, some mark-recapture, catch distribution, and morphological research, indicated that more than one stock exists; one between 175°W and 155°W longitude, and another east of 155° W longitude (Masaki 1976; Masaki 1977). In the U.S. Pacific Exclusive Economic Zone (EEZ) only the Eastern North Pacific Stock is recognized. Worldwide, sei whales were severely depleted by commercial whaling activities. In the North Pacific, the pre-exploitation population estimate for sei whales is 42,000 whales and the most current population estimate for sei whales in the entire North Pacific (from 1977) is 9,110 (NMFS, 2006z).

Application of various models to whaling catch and effort data suggests that the total population of adult sei whales in the North Pacific declined from about 42,000 to 8,600 between 1963 and 1974 (Tillman 1977). Since 500-600 sei whales per year were killed off Japan from 1910 to the late 1950s, the stock size presumably was already, by 1963, below its carrying capacity level

(Tillman 1977). Currently, the best estimate for the Eastern North Pacific stock is 43 (CV = 0.61) individuals (Carretta et al. 2007).

Distribution—Sei whales live in temperate regions of all oceans in the Northern and Southern Hemispheres and are not usually associated with coastal features (NMFS, 2006z). Sei whales are highly mobile, and there is no indication that any population remains in the same area year-round, i.e., is resident. Pole-ward summer feeding migrations occur, and sei whales generally winter in warm temperate or subtropical waters. The species is cosmopolitan, but with a generally anti-tropical distribution centered in the temperate zones. During the winter, sei whales are found from 20°- 23° N and during the summer from 35°-50° N (Masaki 1976; Masaki 1977).

Sei whales are most often found in deep, oceanic waters of the cool temperate zone. They appear to prefer regions of steep bathymetric relief, such as the continental shelf break, canyons, or basins situated between banks and ledges (Kenney and Winn 1987; Schilling et al. 1992; Gregr and Trites 2001; Best and Lockyer 2002). On feeding grounds, the distribution is largely associated with oceanic frontal systems (Horwood 1987). In the North Pacific, sei whales are found feeding particularly along the cold eastern currents (Perry et al. 1999).

Sei whales are known for occasional irruptive occurrences in areas, followed by disappearances for sometimes decades in the Pacific Northwest OPAREA, despite few recent observations. Many British Columbia whaling catches were make in the early to mid 1900s, providing evidence that sei whales have used this area in the past (Pike and MacAskie 1969; Gregr et al. 2000). There is a rare occurrence in the Puget Sound, because sei whales are not expected to occur there. However, a sei whale washed ashore west of Port Angeles during September 2003 (Preston 2003).

Barlow and Forney (2007) estimated sei whale densities for Washington and Oregon of 0.000115 individuals per square km. Off the northern California coast, their density estimate was 0.000182 individuals per square km.

Life History— In the North Pacific, sei whales particularly feed along the cold eastern currents (Perry et al. 1999). In the North Pacific, prey includes calanoid copepods, krill, fish, and squid (Nemoto and Kawamura 1977). The dominant food for sei whales off California during June through August is the northern anchovy, while in September and October they eat mainly krill (Rice 1977). The location of winter breeding areas and characteristics of preferred breeding grounds are unknown (Rice 1998; Perry et al. 1999). Their reproductive cycle is about two years (Gambell 1985).

Diving Behavior—There are no reported diving depths or durations for Sei whales. In lieu of depth data, minke whale depth distribution percentages will be extrapolated to sei whales for use in the acoustic exposure modeling.

Acoustics—Sei whale vocalizations have been recorded only on a few occasions. They consist of paired sequences (0.5 to 0.8 sec, separated by 0.4 to 1.0 sec) of 7 to 20 short (4 milliseconds [msec]) frequency modulated sweeps between 1.5 and 3.5 kHz (Richardson et al. 1995). Sei whales in the Antarctic produced broadband "growls" and "whooshes" at frequency of 433 ±192 kHz and source level of 156 ±3.6 dB re 1 μPa at 1 m (Mc Donald et al. 2005). While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

Impact of human activity-Historic Whaling—Several hundred sei whales in the North Pacific were taken each year by whalers based at shore stations in Japan and Korea between 1910 and the start of World War II (Committee for Whaling Statistics 1942). From 1910 to 1975, approximately 74,215 sei whales were caught in the entire North Pacific Ocean (Perry et al. 1999). The species was taken less regularly and in much smaller numbers by pelagic whalers elsewhere in the North Pacific during this period (Committee for Whaling Statistics 1942). Small numbers were taken sporadically at shore stations in British Columbia from the early 1900s until the 1950s, when their importance began to increase (Pike and MacAskie 1969). More than 2,000 were killed in British Columbia waters between 1962 and 1967, when the last whaling station in western Canada closed (Pike and MacAskie 1969). Small numbers were taken by shore whalers in Washington (Scheffer and Slipp 1948) and California (Clapham et al. 1997) in the early twentieth century, and California shore whalers took 386 from 1957 to 1971 (Rice 1977). Heavy exploitation by pelagic whalers began in the early 1960s, with total catches throughout the North Pacific averaging 3,643 per year from 1963 to 1974 (total 43,719; annual range 1,280-6,053; Tillman 1977). The total reported kill of sei whales in the North Pacific by commercial whalers was 61,500 between 1947 and 1987 (Barlow et al. 1997).

A major area of discussion in recent years has been IWC member nations issuing permits to kill whales for scientific purposes. Since the moratorium on commercial whaling came into effect Japan, Norway, and Iceland have issued scientific permits as part of their research programs. For the last five years, only Japan has issued permits to harvest sei whales although Iceland asked for a proposal to be reviewed by the IWC SC in 2003. The Government of Japan has captured minke, Bryde's, and sperm whales (*Physeter macrocephalus*) in the North Pacific (JARPN II). The Government of Japan extended the captures to include 50 sei whales from pelagic areas of the western North Pacific. Twelve takes of sei whales occurred from 1988 to 1995 in the North Atlantic off Iceland and West Greenland although the IWC has set a catch limit of 0 for all stocks in 1985.

Fisheries Interactions-Sei whales, because of their offshore distribution and relative scarcity in U.S. Atlantic and Pacific waters, probably have a lower incidence of entrapment and entanglement than fin whales. Data on entanglement and entrapment in non-U.S. waters are not reported systematically. Heyning and Lewis (1990) made a crude estimate of about 73 rorquals killed/year in the southern California offshore drift gillnet fishery during the 1980's. Some of these may have been fin whales and some of them sei whales. Some balaenopterids, particularly fin whales, may also be taken in the drift gillnet fisheries for sharks and swordfish along the Pacific coast of Baja California, Mexico (Barlow et al. 1997). Heyning and Lewis (1990) suggested that most whales killed by offshore fishing gear do not drift far enough to strand on beaches or to be detected floating in the nearshore corridor where most whale-watching and other types of boat traffic occur. Thus, the small amount of documentation should not be interpreted to mean that entanglement in fishing gear is an insignificant cause of mortality. Observer coverage in the Pacific offshore fisheries has been too low for any confident assessment of species-specific entanglement rates (Barlow et al. 1997). Sei whales, similar to other large whales, may break through or carry away fishing gear. Whales carrying gear may die later, become debilitated or seriously injured, or have normal functions impaired, but with no evidence recorded.

Ship Strikes—The decomposing carcass of a sei whale was found on the bow of a container ship in Boston harbor, suggesting that sei whales, like fin whales, are killed at least occasionally by

ship strikes (Waring et al. 1997). Sei whales are observed from whale-watching vessels in eastern North America only occasionally (Edds et al. 1984) or in years when exceptional foraging conditions arise (Weinrich et al. 1986; Schilling et al. 1992). There is no comparable evidence available for evaluating the possibility that sei whales experience significant disturbance from vessel traffic.

Other Threats-No major habitat concerns have been identified for sei whales in either the North Atlantic or the North Pacific. However, fishery-caused reductions in prey resources could have influenced sei whale abundance. The sei whale's strong preference for copepods and euphausiids (i.e., low trophic level organisms), at least in the North Atlantic, may make it less susceptible to the bioaccumulation of organochlorine and metal contaminants than, for example, fin, humpback, and minke whales, all of which seem to feed more regularly on fish and euphausiids (O'Shea and Brownell 1995). Since sei whales of the Pacific often feed on pelagic fish as well as invertebrates (Rice 1977), they might accumulate contaminants to a greater degree than do sei whales in the North Atlantic. There is no evidence that levels of organochlorines, organotins, or heavy metals in baleen whales generally (including fin and sei whales) are high enough to cause toxic or other damaging effects (O'Shea and Brownell 1995). It should be emphasized, however, that very little is known about the possible long-term and trans-generational effects of exposure to pollutants.

4.2.5 Sperm whale (*Physeter macrocephalus*)

Stock – California/Oregon/Washington Offshore

Listing Status—Sperm whales have been protected from commercial harvest by the IWC since 1981, although the Japanese continued to harvest sperm whales in the North Pacific until 1988 (Reeves and Whitehead 1997). Sperm whales were listed as endangered under the ESA in 1970. and a draft recovery plan has been prepared (NMFS 2006d). They are also protected by the Convention on International Trade in Endangered Species of wild flora and they are also protected by the Convention on International Trade in Endangered Species of wild flora and fauna and the Marine Mammal Protection Act of 1972. Critical habitat has not been designated for sperm whales.

Population Status—Current estimates for abundance, status, and trends for the Alaska stock of sperm whales are not available (Hill and DeMaster 1999). Approximately 258,000 sperm whales in the North Pacific were harvested by commercial whalers between 1947 and 1987 (Hill and DeMaster 1999). However, this number may be negatively biased by as much as 60% because of under-reporting by Soviet whalers (Brownell et al. 1998). In particular, the Bering Sea population of sperm whales (consisting mostly of males) was severely depleted (Perry et al. 1999). Catches in the North Pacific continued to climb until 1968, when 16,357 sperm whales were harvested. Catches declined after 1968, in part through limits imposed by the IWC (Rice 1989). Reliable estimates of current and historical sperm whale abundance across each ocean basin are not available (NMFS 2006e). Sperm whales are widely distributed across the entire North Pacific Ocean and into the southern Bering Sea in summer, but the majority are thought to occur south of 40°N in winter. Estimates of pre-whaling abundance in the North Pacific are considered somewhat unreliable, but may have totaled 1,260,000 sperm whales. Whaling harvests between 1800 and the 1980s took at least 436,000 sperm whales from the entire North Pacific Ocean (NMFS 2006e).

Several authors have proposed population structures that recognize at least three sperm whales populations in the North Pacific for management purposes (Kasuya 1991, Bannister and Mitchell 1980). At the same time, the IWC's Scientific Committee designated two sperm whale stocks in the North Pacific: a western and eastern stock or population (Donovan 1991). The line separating these populations has been debated since their acceptance by the IWC's Scientific Committee. For stock assessment purposes, NMFS recognizes three discrete population centers of sperm whales in the Pacific: (1) Alaska, (2) California/Oregon/Washington, and (3) Hawai'I (Carretta et al. 2007). California, Oregon, and Washington and those sampled offshore to the Hawaiian Islands (Mesnick et al. 1999; Carretta et al. 2007).

The available data suggest that sperm whale abundance has been relatively stable in California waters since 1979 (Barlow 1994), but there is uncertainty about both the population size and the annual mortality rates. The most recent abundance estimate for sperm whales in the the California/Oregon/Washington stock 2,265 (CV=0.34, Carretta et al. 2007).

Preliminary genetic analyses reveal significant differences between sperm whales off the coast of California, Oregon, and Washington and those sampled offshore to the Hawaiian Islands (Mesnick et al. 1999; Carretta et al. 2007). The NOAA stock assessment report divides sperm whales within the U.S. Pacific EEZ into three discrete, noncontiguous areas: (1) water around the Hawaiian Islands, (2) California, Oregon, and Washington waters, and (3) Alaskan waters (Carretta et al. 2007).

Distribution—Sperm whales occur throughout all ocean basins from equatorial to polar waters, including the entire North Atlantic, North Pacific, northern Indian Ocean, and the southern oceans. Sperm whales are found throughout the North Pacific and are distributed broadly from tropical and temperate waters to the Bering Sea as far north as Cape Navarin. Mature, female, and immature sperm whales of both sexes are found in more temperate and tropical waters from the equator to around 45°N throughout the year. These groups of adult females and immature sperm whales are rarely found at latitudes higher than 50°N and 50°S (Reeves and Whitehead 1997). Sexually mature males join these groups throughout the winter. During the summer, mature male sperm whales are thought to move north into the Aleutian Islands, Gulf of Alaska, and the Bering Sea. Sperm whales are rarely found in waters less than 300 meters in depth. They are often concentrated around oceanic islands in areas of upwelling, and along the outer continental shelf and mid-ocean waters. Sperm whales show a strong preference for deep waters (Rice 1989), especially areas with high sea-floor relief. Sperm whale distribution is associated with waters over the continental shelf edge, over the continental slope, and into deeper waters (Hain et al. 1985; Kenney and Winn 1987; Waring and Finn 1995; Gannier 2000; Gregr and Trites 2001; Waring et al. 2001). However, in some areas, such as off New England, on the southwestern and eastern Scotian Shelf, and in the northern Gulf of California, adult males are reported to use waters with bottom depths <100 m and as shallow as 40 m (Whitehead et al. 1992; Scott and Sadove 1997; Croll et al. 1999; Garrigue and Greaves 2001).

Two noteworthy sperm whale stranding events occurred in the NWTRC. During November 1970, there was an incident that was well-publicized by the media of attempts to dispose of a decomposed sperm whale carcass on an Oregon beach by using explosives. A mass stranding of 47 sperm whales occurred in Oregon during June 1979 (Rice et al. 1986; Norman et al. 2004).

The sperm whale is typically found seaward of the 1,000-m depth in the Pacific Northwest OPAREA and to a lesser extent in water depths of 200 m and 1,000 m. Sperm whale occurrences

in waters between the shore and the 200-m depth are expected to be rare. Sperm whales would have a rare occurrence within the Puget Sound. Based on predictive spatial habitat models, density estimates of sperm whales in the NWTRC ranged from 0 to 0.049 individuals per square km, with an overall density estimate of 0.0026 individuals per square km (DoN 2007a, Appendix B)**.**

Life history information—Female sperm whales become sexually mature at about 9 years of age (Kasuya 1991). Male sperm whales take between 9 and 20 years to become sexually mature, but will require another 10 years to become large enough to successfully compete for breeding rights (Kasuya 1991). Adult females give birth after about 15 months gestation and nurse their calves for 2 to 3 years. The calving interval is estimated to be about four to six years (Kasuya 1991). The age distribution of the sperm whale population is unknown, but sperm whales are believed to live at least 60 years (Rice 1978). Estimated annual mortality rates of sperm whales are thought to vary by age, but previous estimates of mortality rate for juveniles and adults are now considered unreliable (IWC 1980).

Reproduction/Breeding—Calving generally occurs in the summer at lower latitudes and the tropics (DoN 2005).

Diving Behavior—Sperm whales forage during deep dives that routinely exceed a depth of 1,314 ft (400 m) and 30 min duration (Watkins et al. 2002). Sperm whales are capable of diving to depths of over 6,564 ft (2000 m) with durations of over 60 min (Watkins et al. 1993). Sperm whales spend up to 83 percent of daylight hours underwater (Jaquet et al. 2000; Amano and Yoshioka 2003). Males do not spend extensive periods of time at the surface (Jaquet et al. 2000). In contrast, females spend prolonged periods of time at the surface (1 to 5 hours daily) without foraging (Whitehead and Weilgart 1991; Amano and Yoshioka 2003). The average swimming speed is estimated to be 0.7 m/sec (Watkins et al. 2002). Dive descents averaged 11 min at a rate of 1.52 m/sec, and ascents averaged 11.8 min at a rate of 1.4 m/sec (Watkins et al. 2002).

Amano and Yoshioka (2003) attached a tag to a female sperm whale near Japan in an area where water depth was 3,280-4,920 ft (1000-1500 m). For dives with active bottom periods, the total mean dive sequence was 45.9 min (mean surface time plus dive duration). Mean post dive surface time divided by total time (8.5/45.9), plus time at surface between deep dive sequences, yields a percentage of time at the surface (< 33 ft [10 m]) of 31%. Mean bottom time divided by total time (17.5/45.9) and adjusted to include the % of time at the surface between dives, yields a percentage of time at the bottom of the dive (in this case > 2,625 ft [800 m] as the mean maximum depth was 2,755 ft [840 m]) of 34%. Total time in the water column descending or ascending equals duration of dive minus bottom time (37.4-17.5) or ~20 minutes. Assuming a fairly equal descent and ascent rate (as shown in the table) and a fairly consistent descent/ascent rate over depth, we assume 10 minutes each for descent and ascent and equal amounts of time in each depth gradient in either direction. Therefore, 0-656 ft (0-200 m) = 2.5 minutes one direction (which correlates well with the descent/ascent rates provided) and therefore 5 minutes for both directions; and for 657-1,312 ft (201-400 m), 1,313-1,968 ft (401-600 m) and 1,314-2,625 ft (601-800 m). Therefore, the depth distribution for sperm whales based on information in the Amano paper is: 31% in < 33 ft (10 m), 8% in 33-656 ft (10-200 m), 9% in 657-1,312 ft (201-400 m), 9% in 1,313-1,968 ft (401-600 m), 9% in 1,314-2,625 ft (601-800 m) and 34% in > 2,625 ft (800 m). The percentages derived above from data in Amano and Yoshioka (2003) are in fairly close agreement with those derived from Table 1 in Watwood et al. (2006) for sperm whales in the Ligurian Sea, Atlantic Ocean and Gulf of Mexico.

Acoustics—Sperm whales produce short-duration (generally less than 3 sec), broadband clicks from about 0.1 to 30 kHz (Weilgart and Whitehead 1993, 1997; Goold and Jones 1995; Thode et al. 2002) with dominant energy in two bands (2 to 4 kHz and 10 to 16 kHz). The source levels can be up to 236 dB re 1 µPa-m (Møhl et al. 2003). Thode et al. (2002) suggested that the acoustic directivity (angular beam pattern) from sperm whales must range between 10 and 30 dB in the 5 to 20 kHz region. The clicks of neonate sperm whales are very different from usual clicks of adults in that they are of low directionality, long duration, and low-frequency (centroid frequency between 300 and 1,700 Hz) with estimated source levels between 140 and 162 dB re 1 µPa-m (Madsen et al. 2003). Clicks are heard most frequently when sperm whales are engaged in diving/foraging behavior (Whitehead and Weilgart 1991; Miller et al. 2004; Zimmer et al. 2005). These may be echolocation clicks used in feeding, contact calls (for communication), and orientation during dives. When sperm whales are socializing, they tend to repeat series of clicks (codas), which follow a precise rhythm and may last for hours (Watkins and Schevill 1977). Codas are shared between individuals of a social unit and are considered to be primarily for intragroup communication (Weilgart and Whitehead 1997; Rendell and Whitehead 2004). Sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses made by echosounders and submarine sonar (Watkins and Schevill 1975; Watkins et al. 1985). They also stop vocalizing for brief periods when codas are being produced by other individuals, perhaps because they can hear better when not vocalizing themselves (Goold and Jones 1995).

Anatomical studies of the sperm whale's ear suggests that the sperm whale has some high-frequency hearing, but at a lower maximum frequency than many other odontocetes (Ketten, 1992). The sperm whale may also possess better low-frequency hearing than some other odontocetes, although not as extraordinarily low as many baleen whales (Ketten, 1992). The only data on the hearing range of sperm whales are evoked potentials from a stranded neonate (Carder and Ridgway 1991). These data suggest that neonatal sperm whales respond to sounds from 2.5-60 kHz with the highest sensitivity to frequencies between 5 and 20 kHz (Ridgway and Carder, 2001).

Impacts of human activity—In U.S. waters in the Pacific, sperm whales are known to have been incidentally taken only in drift gillnet operations, which killed or seriously injured an average of 9 sperm whales per year from 1991-1995 (Barlow et al. 1997). Of the eight sperm whales observed taken by the California/Oregon drift gillnet fishery, three were released alive and uninjured (37.5 percent), one was released injured (12.5 percent), and four were killed (50 percent) (NMFS 2000). Therefore, approximately 63 percent of captured sperm whales could be killed accidentally or injured (based on the mortality and injury rate of sperm whales observed taken by the U.S. fleet from 1990-2000). Based on past fishery performance, sperm whales are not observed taken in every year; they were observed taken in four out of the last ten years (NMFS 2000). During the three years the Pacific Coast Take Reduction Plan has been in place, a sperm whale was observed taken only once (in a set that did not comply with the Take Reduction Plan; NMFS 2000).

Interactions between longline fisheries and sperm whales in the Gulf of Alaska have been reported over the past decade (Rice 1989, Hill and DeMaster 1999). Observers aboard Alaskan sablefish and halibut longline vessels have documented sperm whales feeding on longline-caught fish in the Gulf of Alaska (Hill and Mitchell 1998) and in the South Atlantic (Ashford and Martin 1996). During 1997, the first entanglement of a sperm whale in Alaska's longline fishery was recorded, although the animal was not seriously injured (Hill and DeMaster 1998). The

available evidence does not indicate sperm whales are being killed or seriously injured as a result of these interactions, although the nature and extent of interactions between sperm whales and long-line gear is not yet clear. Ashford and Martin (1996) suggested that sperm whales pluck, rather than bite, the fish from the long-line.

In 2000, the Japanese Whaling Association announced that it planned to kill 10 sperm whales and 50 Bryde's whales in the Pacific Ocean for research purposes, which would be the first time sperm whales would be taken since the international ban on commercial whaling took effect in 1987. Despite protests from the U.S. government and members of the IWC, the Japanese government harvested 5 sperm whales and 43 Bryde's whales in the last six months of 2000. According to the Japanese Institute of Cetacean Research (Institute of Cetacean Research undated), another 5 sperm whales were killed for research in 2002 – 2003. The consequences of these deaths on the status and trend of sperm whales remains uncertain; however, the renewal of a program that intentional targets and kills sperm whales before we can be certain the population has recovered from earlier harvests places this species at risk in the foreseeable future.

4.2.6 Killer Whale (*Orcinus orca*)

Stock – Eastern North Pacific Southern Resident

Listing Status - The southern resident killer whale is listed as endangered under the ESA. There is designated critical habitat in the Puget Sound and Strait of Juan de Fuca areas of Washington (NMFS Federal Register Nov. 29, 2006). The critical habitat designation encompasses parts of Haro Strait and the waters around the San Juan Islands, the Strait of Juan de Fuca and all of Puget Sound, a total of just over 2,500 square miles. The agency is excluding from the designation 18 military sites covering nearly 112 square miles of habitat. Federal agencies will now be required to consult with NOAA Fisheries Service to ensure their actions will not destroy or adversely modify the killer whales' designated habitat. Critical habitat designation means a more focused analysis on how the action would alter the habitat, and how that will affect the ability of the habitat to support the population's conservation. Critical habitat boundaries are presented in Figure 4-1. A final species recovery plan has been prepared (NMFS 2008).

Population Status – Since the onset of data collection. densus data suggest a slowly increasing population trend (1.8% annually). However, this population stock appears to be down from a peak population of 97 in 1990. The current population is estimated to be about 89 animals (Carretta et al. 2007).

Distribution - Killer whales have been observed in virtually every marine habitat from the tropics to the poles and from shallow, inshore waters (and even rivers) to deep, oceanic regions (Dahlheim and Heyning 1999). In the eastern North Pacific, killer whales range from protected inshore waters to waters off the outer coast (Wiles 2004). Southern resident killer whales spend a significant portion of the year in the inland waterways of the Strait of Georgia, Strait of Juan de Fuca, and Puget Sound, particularly during the spring, summer, and fall. Southern resident killer whales occur in coastal waters of Washington, Oregon, and Vancouver Island and are known to travel as far south as central California. Killer whales in the eastern North Pacific occasionally enter the lower reaches of rivers in Washington and Oregon while feeding (Wiles 2004). In October 1931, a killer whale made its way up the Columbia River and was killed in the Oregon Slough, a branch of Portland Harbor, more than 175 km inland from the Pacific Ocean (Shepherd 1932).

Life History - Killer whales have the most stable social system known among cetaceans. This includes long-term associations between individuals and limited dispersal from maternal pods (Bigg et al. 1990; Baird 2000). Among resident killer whales in the northeastern Pacific, births occur largely from October to March, although births can occur year-round (Olesiuk et al. 1990; Stacey and Baird 1997). Females typically give birth for the first time at 11 to 15 years of age (Ford and Ellis 1999). Maximum life span is estimated to be 80 to 90 years for females and 50 to 60 years for males (Olesiuk et al. 1990).

Reproduction/Breeding - Southern residents feed heavily in areas characterized by high-relief underwater topography, such as subsurface canyons seamounts, ridges, and steep slopes (Heimlich-Boran 1988; Felleman et al. 1991). Salmon are the principle prey for resident killer whales during spring, summer, and fall (Heimlich-Boran 1986; Felleman et al. 1991; Ford et al. 1998; Baird and Hanson 2004; Ford and Ellis 2005; Hanson et al. 2005). Chinook salmon (the area's largest salmonid) are the most commonly targeted species. Other salmonids appear to be eaten less frequently, as are rockfish, halibut, lingcod, and herring.

Diving Behavior. The maximum depth recorded for free-ranging killer whales diving off British Columbia is about 864 ft (263 m) (Baird et al. 2005). On average, however, for seven tagged individuals, less than 1 percent of all dives examined were to depths greater than about 16 fathoms (29 m) (Baird et al. 2003). The longest duration of a recorded dive from a radio-tagged killer whale was 17 min (Dahlheim and Heyning, 1999).

Acoustics - Killer whales produce a wide-variety of clicks and whistles, but most social sounds are pulsed, with frequencies ranging from 0.5 to 25 kHz (dominant frequency range: 1 to 6 kHz) (Thomson and Richardson 1995). Echolocation clicks indicate source levels ranging from 195 to 224 dB re 1 µPa-m peak-to-peak, dominant frequencies ranging from 20 to 60 kHz, and durations of about 0.1 sec (Au et al. 2004). Source levels associated with social sounds have been calculated to range from 131 to 168 dB re 1 µPa-m and vary with vocalization type (Veirs 2004).

Resident killer whales are very vocal, making calls during all types of behavioral states. Acoustic studies of resident killer whales in the Pacific Northwest have found that there are dialects in their highly stereotyped, repetitive discrete calls, which are group-specific and shared by all group members (Ford 1991, 2002b). These dialects likely are used to maintain group identity and cohesion, and may serve as indicators of relatedness that help prevent inbreeding between closely related whales (Ford 1991, 2002b). Dialects have been documented in northern Norway (Ford 2002a) and southern Alaska killer whales populations (Yurk et al. 2002) and likely occur in other regions.

Both behavioral and auditory brainstem response techniques indicate killer whales can hear a frequency range of 1 to 100 kHz and are most sensitive at 20 kHz. This is one the lowest maximum-sensitivity frequencies known among toothed whales (Szymanski et al. 1999).
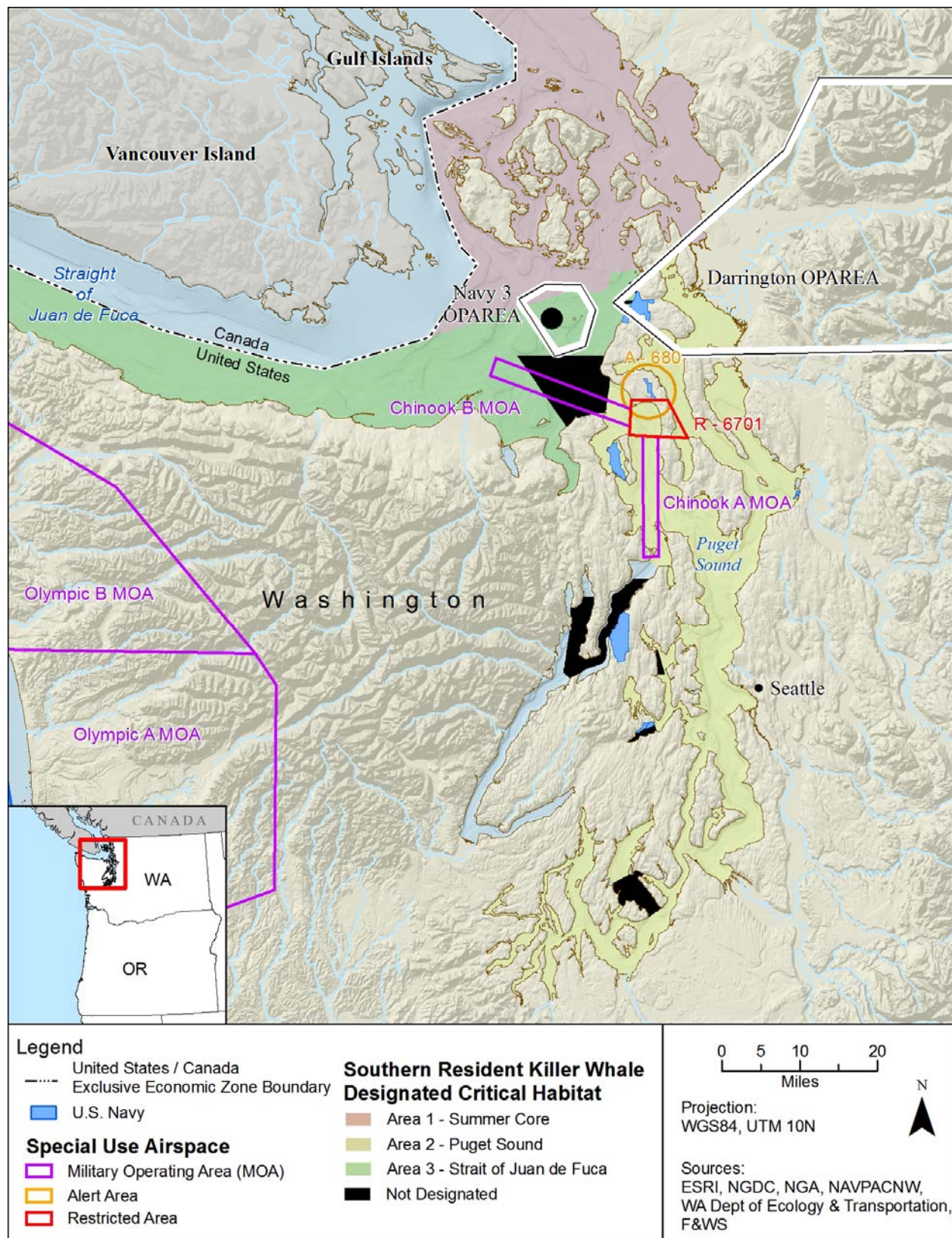
Figure 4-1: Critical Habitat for Southern Resident Killer Whale

4.2.7 Steller Sea Lion (*Eumetopias jubatus*)

Stock – Eastern North Pacific

Listing Status - The Steller sea lion is listed as threatened under the ESA. In 1997, the NMFS reclassified Steller sea lions as two subpopulations, listed the Western stock as endangered under the ESA, and maintained threatened status for the Eastern stock (NMFS 1997c). There is a draft revision to the species recovery plan (NMFS 2008c). Three major rookery sites in Oregon (Rogue Reef, Pyramid Rock; Long Brown Rock; and Seal Rock), three rookery sites in California (Ano Nuevo I; Southeast Farallon I; and Sugarloaf Island and Cape Mendocino) and three large offshore foraging areas in Alaska are designated critical habitat (NMFS FR August 27, 1993). Locations are shown in Figure 4-2.

Population Status - There are two distinct populations, based on genetics and population trends (Angliss and Outlaw 2008). The Western North Pacific stock includes animals at and west of Cape Suckling, Alaska (144°W). The Eastern North Pacific stock includes the animals east of Cape Suckling (NMFS 1997c; Loughlin 2002; Angliss and Outlaw 2007). Census data suggest a decreasing population trend. The minimum population estimate for the eastern stock of the Steller sea lion, which occurs in the Pacific Northwest OPAREA and Puget Sound, is 48,519 individuals (Angliss and Outlaw 2008). Population numbers are thought to be declining.

Distribution - Steller sea lions do not migrate, but they often disperse widely outside of the breeding season (Loughlin 2002). Steller sea lions are gregarious animals that often travel or haul out in large groups of up to 45 individuals (Keple 2002). At sea, groups usually consist of females and subadult males; adult males are usually solitary while at sea (Loughlin 2002). An area of high occurrence extends into the Strait of Juan de Fuca, around San Juan and Whidbey Islands, and through the Strait of Georgia. Another area of high occurrence extends from the shore to the 500-m depth along the outer coast of the OPAREA. The southern part of the Puget Sound as well as the area between the 500-m and 1,000-m depths are less utilized. Steller sea lions are rare seaward of this area.

The current population of 47,885 in the eastern North Pacific includes part of the population found in the NWTRC. The marine mammal density study (DoN 2007a, Appendix B) estimated a density of 0.00011 individuals per square km during the warm season, and 0.011 individuals per square km during the cold season.
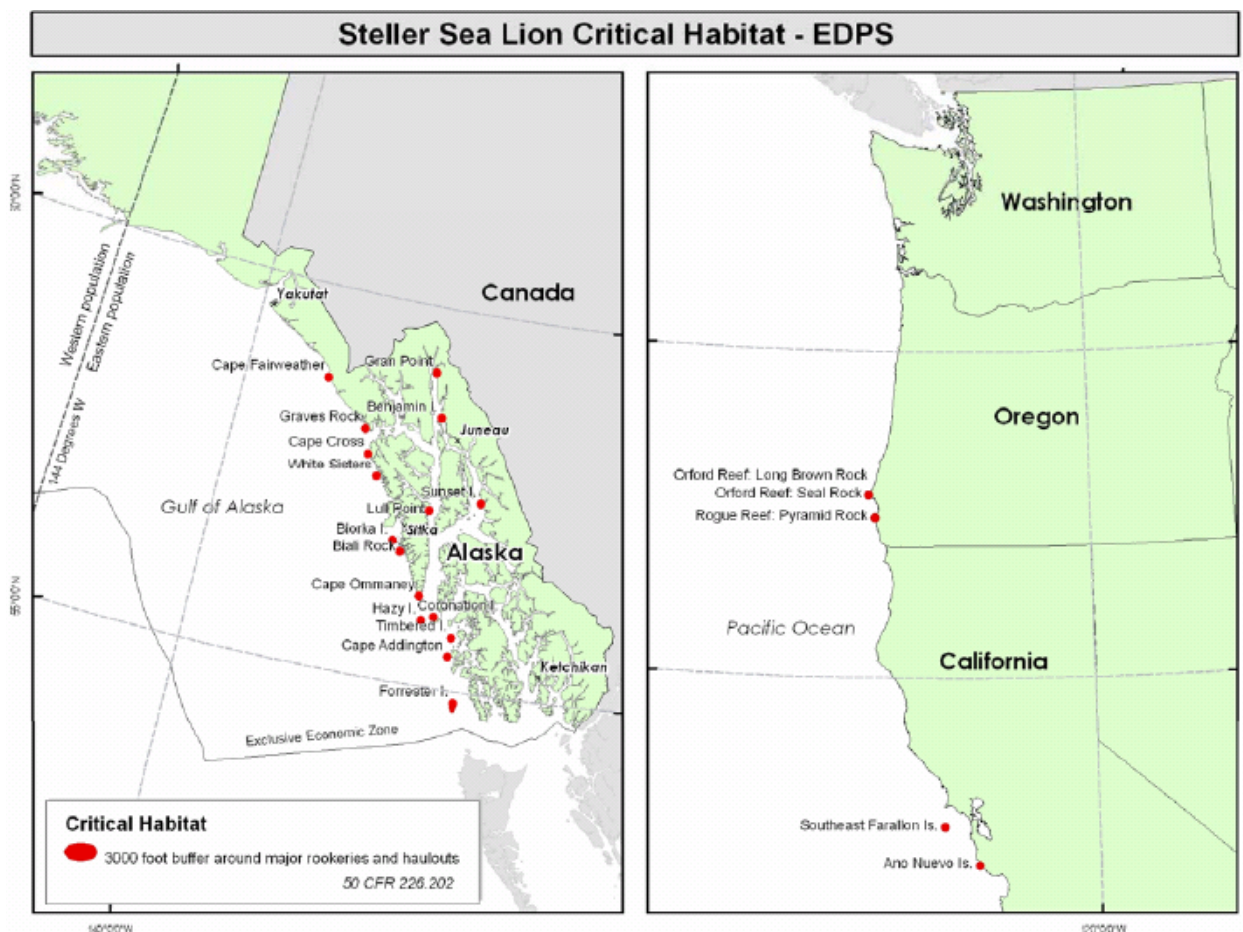
Figure 4-2: Steller Sea Lion Critical Habitat

Life History - Foraging habitat is primarily shallow, nearshore and continental shelf waters, and some Steller sea lions feed in freshwater rivers (Reeves et al. 1992; Robson 2002). They also are known to feed in deep waters past the continental shelf break (Jefferson, T.A., NMFS-SWFSC, pers. comm., March 2005). Haulout and rookery sites are located on isolated islands, rocky shorelines, and jetties. Steller sea lions also haul out on buoys, rafts, floats, and Navy submarines in the Puget Sound (Jeffries et al. 2000; DoN 2001b). Steller sea lions are opportunistic predators, feeding primarily on fish and cephalopods, and their diet varies geographically and seasonally (Merrick et al. 1997). They feed near land or in relatively shallow water (Pitcher and Calkins 1981).

In the Pacific Northwest, breeding rookeries are located in British Columbia, Oregon, and northern California. There are no rookeries in Washington (NMFS 1992; Angliss and Outlaw 2005). Steller sea lions form large rookeries during late spring when adult males arrive and establish territories (Pitcher and Calkins 1981). Large males aggressively defend territories while non-breeding males remain at peripheral sites or haulouts (Pitcher and Calkins 1981). Females arrive soon after and give birth to pups (Pitcher and Calkins 1981). Most births occur from mid-May through mid-July, and breeding takes place shortly thereafter (Pitcher and Calkins 1981).

Most pups are weaned within a year (Pitcher and Calkins 1981). Females reach sexual maturity at 4 to 5 years of age (Pitcher and Calkins 1981).

Acoustics - On land, territorial male Steller sea lions usually produce low-frequency roars (Schusterman et al. 1970; Loughlin et al. 1987). The calls of females range from 30 to 3000 Hz, with peak frequencies from 150 to 1000 Hz; typical duration is 1.0 to 1.5 sec (Campbell et al. 2002). Pups produce bleating sounds. Underwater sounds are similar to those produced on land (Loughlin et al. 1987).

When the underwater hearing sensitivity of two Steller sea lions was tested, the hearing threshold of the male was significantly different from than that of the female. The range of best hearing for the male was from 1 to 16 kHz, with maximum sensitivity (77 dB re 1 µPa-m) at 1 kHz. The range of best hearing for the female was from 16 to above 25 kHz, with maximum sensitivity (73 dB re 1 µPa-m) at 25 kHz. However, because of the small number of animals tested, the findings could not be attributed to individual differences in sensitivity or sexual dimorphism (Kastelein et al. 2005).

4.2.8 Sea otter (*Enhydra lutris nereis*)

Stock – California and Washington (Southern sea otter)

Listing Status—The sea otter falls under the regulatory oversight of the USFWS, while all other species of marine mammals occurring within the NWTRC fall under the regulatory oversight of NMFS. The southern sea otter is listed as threatened under the ESA. If restrictions on the use of gill and trammel nets in areas inhabited by southern sea otters were lifted, the southern sea otter population would be designated as a strategic stock as defined by the MMPA (USFWS, 1995 in Carretta et al. 2007).

Population Status—Until recent years, the northern population had increased to well over 100,000 individuals, while the southern or California population had grown more slowly, apparently because of a lower rate of pup survival (Riedman et al. 1994). Except during 1976–1983, the southern population increased steadily between 1983-1994 at a rate of five to seven percent since it received protection in 1911.

Distribution—Historically, sea otters occupied a large range throughout the northern Pacific Coastal region, extending from Russia and Alaska to Mexico (Kenyon 1969). Harvests of sea otters in the 18th and 19th centuries nearly exterminated the species (Orr and Helm 1989). The southern sea otter's primary range is restricted to the coastal area of central California, from Point Año Nuevo to south of Point Conception (Orr and Helm 1989; USFWS 1996, 2005), plus a small translocated population around San Nicolas Island that diminished to about 17 by 1995, which was not considered viable because the population size was too small (Ralls et al. 1995; USFWS 1996). As the population has increased, its range has also expanded.

Based on known use, there is an area of high utilization for the sea otter between the shore and bottom depth of 40 m from Neah Bay, around the Olympic Peninsula, to Grays Harbor. A secondary occurrence is located in this same area between the 40-m and 100-m depths. All of the Puget Sound is an area of secondary occurrence (Lynch, D., USFWS, pers. comm., 29 November 2005). The Oregon coast from the shore to the 100-m depth is an area of secondary occurrence, based on the historical range of the species and recent sightings that indicate that the species may be expanding its range. There is a rare occurrence offshore from, and south of, the coastal areas of secondary occurrence.

The pre-exploitation range of the sea otter included the entire Washington coast, with a major concentration off Point Grenville (Lance et al. 2004). The current population of 743 occurs along 185 km of coastline from Destruction Island in the south to Pillar Point (Neah Bay) in the north, with concentrations at Duk Point, Cape Alava, Sand Point, Cape Johnson, Perkins Reef, and Destruction Island (Lance et al. 2004). Almost half the Washington population occurs at Destruction Island (Lance et al. 2004). Recent sightings have been made as far south as Cape Elizabeth (Calambokidis et al. 2004b; Doughton 2004).

Although the sea otter is not usually seen in the Puget Sound (Osborne et al. 1988), there are confirmed sightings and movements of tagged individuals in the eastern Strait of Juan de Fuca, around the San Juan Islands, and within the Puget Sound near Olympia (Calambokidis et al. 1987; Lance et al. 2004). Prior to recent sightings, the Strait of Juan de Fuca had not been occupied by sea otters for over 100 years (Jeffries et al. 2005). One sea otter was sighted about nine km inland up McAllister Creek (Jeffries and Allen 2001).

Most of Oregon's historical sea otter habitat occurs in the southern half of the state in the extensive nearshore rocky reef systems. However, the population was extirpated by hunting and, for unknown reasons, reintroduction has not been successful (Jameson et al. 1982). However, confirmed sightings of sea otters along the Oregon coast have increased over the past decade and include sightings at Cape Blanco, Yachats, Yaquina Bay, and Simpson Reef at Cape Arago (Lynch, D., USFWS, pers. comm., 29 November 2005; Quinn).

In the last 10 years, there have been only two confirmed sightings of sea otters in northern California. Because these were on consecutive days in August 2005 (Hatfield, B., USGS, pers. comm., 7 September 2005), they probably involved a single animal.

There are no density calculations for this species in the NWTRC.

Life History— Sea otters feed on or near the bottom in shallow water. The diet varies with physical and biological habitat characteristics (Riedman and Estes 1990; Estes and Bodkin 2002). Large sea urchins are the preferred prey, to the extent that urchin density and large size classes can be depleted and the otters are forced to a more diverse diet (Kvitek et al. 1989; Kvitek et al. 1998; Kvitek et al. 2001; VanBlaricom and Chambers 2003; Laidre et al. 2004). Along the Washington coast, their diverse diet includes crustaceans, bivalves, urchins, and sea cucumbers (Bowlby et al. 1988; Lance et al. 2004; Jeffries et al. 2005). They also prey on cephalopods, fish, and seabirds (Riedman and Estes 1990). Sea otters occupying new habitat in the Strait of Juan de Fuca have a diet dominated by red urchins (Jeffries et al. 2005).

Sea otters may be sighted alone or in groups, called "rafts" (Riedman and Estes 1990). Adult males establish territories, and females move freely among males' territories (Jameson 1989). Females and males attain sexual maturity at three and five years of age, respectively (USFWS 2003b). Breeding and pupping occur throughout the year, with a breeding peak in late autumn in Washington and most births occurring from late February to early April (USFWS 2003b; Lance et al. 2004). Most adult female sea otters give birth to a single pup each year (Jameson and Johnson 1993).

Diving Behavior—Sea otters feed on or near the bottom in shallow waters, often in kelp beds. Major prey items are benthic invertebrates such as abalones, sea urchins, and rock crabs. Sea otters also eat other types of shellfish, cephalopods, and sluggish near-bottom fishes. The diet varies with the physical and biological characteristics of the habitats in which they live (reviews

by Riedman and Estes 1990; Estes and Bodkin 2002). Sea otters exhibit individual differences not only in prey choice, but also in choice and method of tool use, area in which they tend to forage, and water depth (Riedman and Estes 1990; Estes et al. 2003b). In rocky-bottom habitats, sea otters generally forage for large-bodied prey offering the greatest caloric reward. In softbottom habitats, prey is smaller and more difficult to find; sea otters feed on a variety of burrowing invertebrates. Sea otters in California typically forage in waters with a bottom depth less than 25 m though individuals have been sighted foraging in waters with a bottom depth as great as 36 m (Riedman and Estes 1990; Ralls et al. 1995). The record dive depth occurred in the Aleutian Islands, where a sea otter drowned in a king crab pot set at a bottom depth of approximately 100 m (Riedman and Estes 1990). Mean dive duration exceeds 125 sec (Ralls et al. 1995).

Sea otters spend about one-quarter to one-third of their time foraging to meet metabolic needs. They dive to the bottom to collect crabs, clams, urchins, and mussels, and return to the surface to open and consume prey. Tinker et al. (2007) collected dive and forage data via time-depth recorders on otters in California. Their data indicate that 36-52% of time was spent at the surface between dives, depending on the size and type of prey being consumed. Sea otters usually dive to less than 30 m for food (Lance et al. 2004). Using this information, the following are estimated time at depth for sea otters: 50% at <1 m, 50% at 1-30 m.

Acoustics—Sea otter vocalizations are considered to be most suitable for short range communication among individuals (McShane et al. 1995). Airborne sounds include screams; whines or whistles; hisses; deep-throated snarls or growls; soft cooing sounds; grunts; and barks (Kenyon 1975; McShane et al. 1995). The high-pitched, piercing scream of a pup can be heard from distances of greater than 1 km (McShane et al. 1995). In-air mother-pup contact vocalizations have most of their energy at 3 to 5 kHz, but there are higher harmonics (McShane et al. 1995; Richardson et al. 1995). There is no hearing data available for this species (Ketten 1998).

4.3   Non-Endangered and Non-Threatened Species

Other marine mammal species occurring within southern California are described below. All of these species, while protected under the MMPA, are not listed as endangered under the ESA, and nor considered depleted or strategic under the MMPA

4.3.1 Baleen Whales (Sub-Order Mysticeti)

4.3.1.1   Gray whale (*Eschrichtius robustus*)

Stock - Eastern North Pacific Stock

Population Status—The Eastern North Pacific stock was believed to consist of 18,178 individuals in 2002 (Anglis and Outlaw 2008. This estimate is lower than previous estimates in 1997–1998 (26,635; CV=0.101; Hobbs and Rugh [1999]), 1993–1994 (23,109; CV=0.054; Laake et al. [1994]) and 1995–1996 (22,263; CV=0.093; Hobbs et al. [1996]).

Distribution—The gray whale makes a well-defined seasonal north-south migration (Fig. 10). Most of the population summers in the shallow waters of the northern Bering Sea, the Chukchi Sea, and the western Beaufort Sea (Rice and Wolman 1971), whereas some individuals also summer along the Pacific coast from Vancouver Island to central California (Rice and Wolman 1971; Darling 1984; Nerini 1984). In October and November, the whales begin to migrate

southeast through Unimak Pass and follow the shoreline south to breeding grounds on the west coast of Baja California and the southeastern Gulf of California (Braham 1984; Rugh 1984). The average gray whale migrates 7,500–10,000 km at a rate of 147 km/d (Rugh et al. 2001; Jones and Swartz 2002). Although some calves are born along the coast of California, most are born in the shallow, protected waters on the Pacific coast of Baja California from Morro de Santo Domingo (28°N) south to Isla Creciente (24°N) (Urban et al. 2003). The main calving sites are Laguna Guerrero Negro, Laguna Ojo de Liebre, Laguna San Ignacio, and Estero Soledad (Rice et al. 1981).

Gray whales occur in the Pacific Northwest OPAREA and Puget Sound throughout the year. In addition, larger numbers of migratory animals transit along the coast of Washington, Oregon, and California during migrations between breeding and feeding grounds. Peak sightings in the NWTRC during the southbound migration occur in January (Rugh et al. 2001). There are two phases of the northbound migration, including an early phase from mid-February through April and a later phase, which consists of mostly cows and calves, from late April through May (Herzing and Mate 1984).

Some whales enter Willapa Bay, Grays Harbor, the Strait of Juan de Fuca, and the Puget Sound during migration (Richardson 1997b; Calambokidis et al. 2004b). In recent years, gray whales have been sighted in the southern part of Puget Sound, particularly in Elliott Bay. Gray whales are known to enter the Puget Sound in spring and remain there through the early summer months; some are present in the region as early as January (Calambokidis et al. 1994). Most sightings in the Puget Sound are between March and May (Calambokidis et al. 1994; DoN 2002).

A group of a few hundred gray whales known as the Pacific Coast Feeding Aggregation (PCFA) feeds along the Pacific coast between southeastern Alaska and southern California throughout the summer and fall (NMFS 2001; Calambokidis et al. 2002). Gray whales that summer in Washington waters feed on benthic invertebrates, including dense aggregations of ghost shrimp in the Puget Sound (Weitkamp et al. 1992; Richardson 1997b).

There is concern that the resumption of whaling by the Makah Indian Tribe of Washington may negatively impact the PCFA. (Calambokidis et al. 2002). Based on the 1855 Treaty of Neah Bay, the Makah Indian Tribe has the right to hunt gray whales at usual and accustomed grounds off the coast of Washington (NMFS 2005d). The Makah hunted gray whales until the 1920s when the eastern population was drastically reduced. After the eastern population was delisted from the ESA in 1994, the Makah hunted one gray whale in 1999 but have since been prevented from whaling (NMFS 2005d). The Makah recently submitted a request to hunt 20 gray whales within a 5-year period. The Makah's proposal includes time and area restrictions to avoid intentional harvest of PCFA whales and management measures to ensure that any incidental harvest of PCFA whales remains at or below the annual strike limit (NMFS 2005d).

The highest area of occurrence in the NWTRC is from the shore to a water depth of 200 m. Some individuals that might migrate farther offshore an additional 10 nm (18.5 km) but seaward of this, there is a rare occurrence of gray whales.

Within the Puget Sound, the area of high utilization extends from the outer coast into the Strait of Juan de Fuca to north of the Kitsap Peninsula (about 47°N), including the area around Whidbey Island. This also includes Boundary Bay, which is often occupied by gray whales from March to June (Ford, J., DFO, pers. comm., 9 January 2006). An area of lower occurrence south of the

Kitsap Peninsula accounts for possible sightings of this species in southern Puget Sound. An area of lower occurrence north of the San Juan Islands is based on historic whaling catches in the Strait of Georgia.

There are currently no density estimates for gray whales in the NWTRC.

Life history—When foraging, gray whales typically dive to 50 to 60 m for 5 to 8 min. In the breeding lagoons, dives are usually less than 6 min (Jones and Swartz 2002), although dives as long as 26 min have been recorded (Harvey and Mate 1984). When migrating, gray whales may remain submerged near the surface for 7 to 10 min and travel 500 m or more before resurfacing to breathe. The maximum known dive depth is 170 m (Jones and Swartz 2002). Migrating gray whales sometimes exhibit a unique "snorkeling" behavior in which they surface cautiously, exposing only the area around the blow hole, exhale quietly without a visible blow, and sink silently beneath the surface (Jones and Swartz 2002). Breeding grounds consist of subtropical lagoons that are protected from the open ocean (Jones and Swartz 2002). Although some calves are born along the coast of southern California, most are born in the shallow, protected waters on the Pacific coast of Baja California (Urban et al. 2003).

Diving Behavior—When foraging, gray whales typically dive to 50 to 60 m for 5 to 8 min. In the breeding lagoons, dives are usually less than 6 min (Jones and Swartz, 2002), although dives as long as 26 min have been recorded (Harvey and Mate 1984). When migrating, gray whales may remain submerged near the surface for 7 to 10 min and travel 500 m or more before resurfacing to breathe. The maximum known dive depth is 170 m (Jones and Swartz 2002). Migrating gray whales sometimes exhibit a unique "snorkeling" behavior in which they surface cautiously, exposing only the area around the blow hole, exhale quietly without a visible blow, and sink silently beneath the surface (Jones and Swartz 2002).

Mate and Urban Ramirez (2003) noted that 30 of 36 locations for a migratory gray whale with a satellite tag were in water <100m deep, with the deeper water locations all in the southern California Bight within the Channel Islands. Whales in that study maintained consistent speed indicating directed movement. There has been only one study yielding a gray whale dive profile, and all information was collected from a single animal that was foraging off the west coast of Vancouver Island (Malcolm and Duffus, 2000; Malcolm et al.1995/96). They noted that the majority of time was spent near the surface on interventilation dives (<3 m depth) and near the bottom (extremely nearshore in a protected bay with mean dive depth of 18 m, range 14-22 m depth). There was very little time spent in the water column between surface and bottom. Foraging depth on summer feeding grounds is generally between 50-60 m (Jones and Swartz, 2002). Based on this very limited information, the following is a rough estimate of depth distribution for gray whales: 50% at <4 m (surface and interventilation dives), 50% at 4-18 m.

Acoustics—Au (2000) reviewed the characteristics of gray whale vocalizations. Gray whales produce broadband signals ranging from 100 Hz to 4 kHz (and up to 12 kHz) (Dahlheim et al. 1984; Jones and Swartz 2002). The most common sounds on the breeding and feeding grounds are knocks (Jones and Swartz 2002), which are broadband pulses from about 100 Hz to 2 kHz and most energy at 327 to 825 Hz (Richardson et al. 1995). The source level for knocks is approximately 142 dB re 1 μPa-m (Cummings et al. 1968). During migration, individuals most often produce low-frequency moans (Crane and Lashkari 1996). The structure of the gray whale ear is evolved for low-frequency hearing (Ketten, 1992). The ability of gray whales to hear frequencies below 2 kHz has been demonstrated in playback studies (Cummings and Thompson

1971; Dahlheim and Ljungblad 1990; Moore and Clarke 2002) and in their responsiveness to underwater noise associated with oil and gas activities (Malme et al. 1986; Moore and Clarke 2002). Gray whale responses to noise include changes in swimming speed and direction to move away from the sound source; abrupt behavioral changes from feeding to avoidance, with a resumption of feeding after exposure; changes in calling rates and call structure; and changes in surface behavior, usually from traveling to milling (e.g., Moore and Clarke 2002).

4.3.1.2 Minke whale (*Balaenoptera acutorostrata*)

Stock - California/Oregon/Washington

Population Status— NMFS recognizes three stocks of minke whales off the U.S. coast. These include a California, Oregon, and Washington stock, an Alaskan stock, and a Hawaiian stock (Carretta et al. 2006). The current abundance estimate based on five survey years (1991, 1993, 1996, 2001, and 2005) estimates the minke whale population to be 898 (CV=0.65) for the California/Oregon/Washington stock (Carretta et al. 2007).

Distribution—In the Northeast Pacific Ocean, minke whales range from the Chukchi Sea south to Baja California (Leatherwood et al. 1987). They occur year-round off California (Dohl et al. 1983; Barlow 1995; Forney et al. 1995). The minke whales found in waters off California, Oregon, and Washington appear to be resident in that area, and to have home ranges, whereas those farther north are migratory. The minke whale generally occupies waters over the continental shelf, including inshore bays and estuaries (Mitchell and Kozicki 1975; Ivashin and Vitrogov, 1981; Calambokidis et al. 2004). However, based on whaling catches and surveys worldwide, there is also a deep-ocean component to the minke whale's distribution (Slijper et al. 1964; Horwood 1990; Mitchell 1991; Mellinger et al. 2000; Roden and Mullin 2000).

Minke whales appear to establish home ranges in the inland waters of Washington and along central California (Dorsey 1983; Dorsey et al. 1990), and exhibit site fidelity to these areas between years (Dorsey et al. 1990). They are observed year-round in the Puget Sound, with a peak in abundance between July and September (Everitt et al. 1979; Osborne et al. 1988; Dorsey et al. 1990). There is an area of rare occurrence seaward of these areas.

Dorsey et al. (1990) noted minke whales feeding in locations of strong tidal currents in inland waters of the Puget Sound. Hoelzel et al. (1989) reported that 80% of feeding observations in the San Juans were over submarine slopes of moderate incline at a depth of about 20 m to 100 m. Prey taken in the San Juans included juvenile herring (*Clupea harengus*) and probably sand lance (Hoelzel et al. 1989). Off the California outer coast, they foraged along the edge of kelp beds and out to the shelf break (Dorsey et al. 1990) in contrast to other locales where minkes forage from closer to shore to the edge of the shelf break (Stern, J., Northeast Pacific Minke Whale Project, pers. comm., 11 November 2005).

Within the Puget Sound, there is an area of high utilization around the San Juan Islands and in the Strait of Juan de Fuca. This area extends into Admiralty Inlet on the west side of Whidbey Island. Within this area, individuals move within and between specific feeding areas around submarine banks (Stern, J., Northeast Pacific Minke Whale Project, pers. comm., 11 November 2005). Three feeding grounds were identified: the Strait of Juan de Fuca, including all of the submarine banks; San Juan Channel and the Waldron Island area, including Cowlitz Bay, President's Channel, and Rosario Strait; and between Sucia, Patos, and Waldron Islands (Osborne et al. 1988; Hoelzel et al. 1989; Dorsey et al. 1990; Stern, J., Northeast Pacific Minke

Whale Project, pers. comm., 11 November 2005). There are probably other feeding areas in the Puget Sound, and there is year-to-year variation in the use of some of these areas (Osborne et al. 1988; Dorsey et al. 1990).

There are areas of lower utilization and rare occurrence along the outer coast; the dividing line between these areas is based on available sighting records. The inland waters of the Puget Sound also are identified as an area of low utilization. The frequency of sightings of minke whales in inland waters is very low in winter months (Everitt et al. 1979; Dorsey et al. 1990).

Barlow and Forney (2007) estimated the density of minke whales off the coast of Washington and Oregon to be 0.000655 individuals per square km. Off the California coast, their estimate was 0.000395 individuals per square km.

Life History - In the North Pacific, major food items include krill, Japanese anchovy, Pacific saury, herring, sand lance, and walleye pollock (Perrin and Brownell 2002; Stern, J., Northeast Pacific Minke Whale Project, pers. comm., 31 July 2006). Although minke whales are distributed in polar, temperate, and tropical waters (Jefferson et al. 1993), there is no obvious migration from low-latitude, winter breeding grounds to high-latitude, summer feeding locations in the western North Pacific (Horwood 1990). Stewart and Leatherwood (1985) suggested that mating occurs in winter or early spring although it had never been observed.

Diving Behavior—Stern (1992) described a general surfacing pattern of minke whales consisting of about four surfacings, interspersed by short-duration dives averaging 38 sec. After the fourth surfacing, there was a longer duration dive ranging from approximately 2 to 6 min. Minke whales are "gulpers," like the other rorquals (Pivorunas 1979). Hoelzel et al. (1989) reported on different feeding strategies used by minke whales. In the North Pacific, major food items include krill, Japanese anchovy, Pacific saury, and walleye Pollock (Perrin and Brownell 2002).

The only depth distribution data for this species are reported from a study on daily energy expenditure conducted off northern Norway and Svalbard (Blix and Folkow 1995). The limited depth information available (from Figure 2 in Blix and Folkow 1995) is representative of a 75-min diving sequence where the whale was apparently searching for capelin, then foraging, then searching for another school of capelin. Search dives were mostly to ~20 m, while foraging dives were to 65 m. Based on this very limited depth information, rough estimates for % of time at depth are as follows: 53% at <20 m and 47% at 20-65 m.

Acoustics—Recordings in the presence of minke whales have included both high- and low-frequency sounds (Beamish and Mitchell 1973; Winn and Perkins 1976; Mellinger et al. 2000). Mellinger et al. (2000) described two basic forms of pulse trains that were attributed to minke whales: a "speed up" pulse train with energy in the 200 to 400 Hz band, with individual pulses lasting 40 to 60 msec, and a less-common "slow-down" pulse train characterized by a decelerating series of pulses with energy in the 250 to 350 Hz band. Recorded vocalizations from minke whales have dominant frequencies of 60 Hz to greater than 12,000 Hz, depending on vocalization type (Richardson et al. 1995). Recorded source levels, depending on vocalization type, range from 151 to 175 dB re 1 µPa-m (Ketten 1998). Gedamke et al. (2001) recorded a complex and stereotyped sound sequence ("star-wars vocalization") in the Southern Hemisphere that spanned a frequency range of 50 Hz to 9.4 kHz. Broadband source levels between 150 and 165 dB re 1 µPa-m were calculated. "Boings," recently confirmed to be produced by minke whales and suggested to be a breeding call, consist of a brief pulse at 1.3 kHz, followed by an amplitude-modulated call with greatest energy at 1.4 kHz, with slight frequency modulation over

a duration of 2.5 sec (Anonymous 2002; Rankin and Barlow 2003). While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

4.3.2 Toothed whales (Sub-Order Odontoceti)

4.3.2.1 Baird's beaked whale (*Berardius bairdii*)

Stock – California/Oregon/Washington

Population Status—Population size for the California/Oregon/Washington Stock is estimated to be 313 (CV=0.55) individuals (Carretta et al. 2007).

Distribution—Baird's beaked whales appear to occur mainly in deep waters over the continental slope, oceanic seamounts, and areas with submarine escarpments (Ohsumi 1983; Kasuya and Ohsumi 1984; Willis and Baird 1998; Kasuya 2002). They may be seen close to shore where deep water approaches the coast (Jefferson et al. 1993) and in shallow waters in the central Okhotsk Sea (Kasuya 2002). Recent information suggests that some beaked whales (Blaineville's and Cuvier's beaked whales, and northern bottlenose whales) show site fidelity and can be sighted in the area over many years (Hooker et al. 2002; Wimmer and Whitehead 2005; McSweeney et al. 2007).

The Baird's beaked whale probably is a slope-associated species. As a result, the area of highest utilization for this whale in the Pacific Northwest OPAREA is in waters deeper than 500 m. The area of lower utilization is between 200 m to 500 m water depth. There is a rare occurrence in waters shallower than 200 m. The majority of the Puget Sound is an area of rare occurrence for this species, except the deeper waters of the Strait of Juan de Fuca where there is an area of secondary occurrence.

Barlow and Forney (2007) estimated Baird's beaked whale densities for Washington and Oregon of 0.001614 individuals per square km. Off the northern California coast, their density estimate was 0.000775 individuals per square km.

Life History – Baird's beaked whales occur in relatively large groups of 6 to 30, and groups of 50 or more sometimes are seen (Balcomb 1989). They feed mainly on benthic fish and cephalopods, but prey also includes pelagic fish such as mackerel, sardine, and saury (Kasuya 2002; Walker et al. 2002; Ohizumi et al. 2003). Baird's beaked whales in Japan prey primarily on deepwater gadiform fishes and cephalopods, indicating that they feed primarily at depths ranging from 800 to 1,200 m (Walker et al. 2002; Ohizumi et al. 2003). Sexual maturity occurs at about 8 to 10 years, and the calving peak is in March and April (Balcomb 1989). Mating generally occurs in October and November but little else is known of their reproductive behavior (Balcomb 1989).

Diving Behavior—Analysis of stomach contents from captured and stranded individuals suggests that beaked whales are deep-diving animals, feeding by suction (Heyning and Mead 1996). The Baird's beaked whale, feeds mainly on benthic fishes and cephalopods, but occasionally on pelagic fish such as mackerel, sardine, and saury (Kasuya 2002; Walker et al. 2002; Ohizumi et al. 2003). Baird et al. (2006) reported on the diving behavior of four Blaineville's beaked whales (a similar species) off the west coast of Hawaii. The four beaked whales foraged in deep ocean areas (2,270-9,855ft) with a maximum dive to 4,619 ft (1,407 m). Dives ranged from at least 13 min (lost dive recorder during the dive) to a maximum of 68 min (Baird et al. 2006).

In lieu of other information, the depth distribution for northern bottlenose whales, Hyperoodon ampullatus, will be extrapolated to Baird's. There has been one study on northern bottlenose whales, which provides some guidance as to depth distribution (Hooker and Baird 1999). Most (62-70%, average = 66%) of the time was spent diving (deeper than 40 m), and most dives were somewhat V-shaped. Both shallow dives (<400 m) and deep dives (>800 m) were recorded, and whales spent 24-30% (therefore, average of 27%) of dives at 85% maximum depth indicating they feed near the bottom. Using these data points, we estimate 34% of time at 0-40 m, 39% at 41-800 m, 27% at >800 m for *H. ampullatus* and extrapolate this to *B. berardius*.

Acoustics—MacLeod (1999) suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Both whistles and clicks have been recorded from Baird's beaked whales in the eastern North Pacific Ocean (Dawson et al. 1998). Whistles had fundamental frequencies between 4 and 8 kHz, with 2 to 3 strong harmonics within the recording bandwidth (Dawson et al. 1998). Pulsed sounds (clicks) had a dominant frequency around 23 kHz, with a second frequency peak around 42 kHz (Dawson et al. 1998). The clicks were most often emitted in irregular series of very few clicks; this acoustic behavior appears unlike that of many species that do echolocate (Dawson et al. 1998). Cuvier's beaked whales echolocation clicks were recorded at frequencies from 20 to 70 kHz (Zimmer et al. 2005).

While there is no information on the hearing abilities of Baird's beaked whale, Cook et al. (2006) reported that the Gervais beaked whale (*Mesoplodon europeus*), a conspecific whale, could hear in the range of 5 to 80 kHz although no measurements were attempted above 80 kHz. The Gervais beaked whale was most sensitive from 40 to 80 kHz (Cook et al. 2006).

4.3.2.2 Bottlenose dolphin, Offshore (*Tursiops truncatus*)

Stock – California/Oregon/Washington Offshore

Population Status— Bottlenose dolphins within the Pacific waters of the U.S. are divided into three stocks: the California coastal stock; California, Oregon, and Washington offshore stock; and Hawaiian stock (Carretta et al. 2007). Bottlenose dolphins found in the Pacific Northwest OPAREA and Puget Sound could be from the California coastal stock or the California, Oregon, Washington offshore stock. The best abundance estimate for the California, Oregon, Washington offshore stock is 3,257 (CV = 0.43) individuals (Carretta et al. 2007).

Distribution— These dolphins live in coastal areas of all continents, around many oceanic islands and atolls, and over shallow offshore banks and shoals. There are also pelagic populations that range far from land (Miyashita 1993; Reeves et al. 2002). In the eastern North Pacific, the distribution of coastal bottlenose dolphins extends from at least Ensenada, Baja California, Mexico to Monterey Bay, California, with occasional sightings at San Francisco (Orr 1963; Ferrero and Tsunoda 1989; Bonnell and Dailey 1993; Maldini-Feinholz 1996). The northernmost record in the eastern North Pacific is a stranding that occurred in March 1988 near Colony Creek, 100 km north of Seattle (Osborne and Ransom 1988; Ferrero and Tsunoda 1989). Individuals have been documented in offshore waters as far north as about 41°N; they may range into Oregon and Washington waters during warm-water periods (Carretta et al. 2007). There is an area of rare occurrence for the bottlenose dolphin throughout the Pacific Northwest OPAREA and Puget Sound. Barlow and Forney (2007) estimated offshore bottlenose densities off the northern California coast as 0.000515 individuals per square km.

Reproduction/Breeding—Bottlenose dolphins are opportunistic feeders on fish, cephalopods, and shrimp (Wells and Scott 1999). Sound is important to feeding strategies, and includes both active echolocation to find food and passive listening to detect and orient to fish prey (Barros and Myrberg 1987; Gannon et al. 2005). Bottlenose dolphins are gregarious, typically occurring in groups of 2 to 15, although groups can include 100 or more animals (Shane et al. 1986). Bottlenose dolphins reach physical maturity at about 13 years (Mead and Potter 1990). Newborn calves are seen throughout the year and reproduction may be influenced by productivity and food abundance (Urian et al. 1996) though calving peaks have not been determined (Weller, D., NMFS-SWFSC, pers. comm., 15 April 2005).

Diving Behavior—Offshore bottlenose dolphins in the Bahamas dove to depths below 450 m and for over 5 min during the night but dives were shallow (<50m) during the day (Klatsky et al. 2007). In contrast, the dives of offshore bottlenose dolphins off the east coast of Australia were mostly within 5 m of the surface (approximately 67% of dives) with the deepest dives to only 150 meters (Corkeron and Martin 2004). A comparison of hemoglobin concentration and hematocrit, important to oxygen storage for diving, between Atlantic coastal and offshore bottlenose dolphins shows higher levels of both in offshore dolphins (Hersh and Duffield 1990). The increase in hemoglobin and hematocrit suggest greater oxygen storage capacity in the offshore dolphin which may allow it to dive longer in the deep offshore areas that they inhabit.

Based on data presented in Klatsky et al. (2007), the following depth distribution has been estimated for offshore bottlenose dolphins: Daytime: 96% at <50 m, 4% at >50 m; nightime: 51% at <50 m, 8% at 50-100 m, 19% at 101-250 m, 13% at 251-450 m and 9% at >450 m. Data on time spent at the surface were not published, therefore, it was included in the least shallow depth category published.

Acoustics—Sounds emitted by bottlenose dolphins include pulsed sounds (clicks and burst-pulses) and narrow-band continuous sounds (whistles) that usually are frequency-modulated. Ketten (1998) found that clicks and whistles have a dominant frequency range of 110 to 130 kHz and a source level of 218 to 228 dB re 1 µPa-m (Au 1993) and 3.5 to 14.5 kHz and 125 to 173 dB re 1 µPa-m, respectively. Thomson and Richardson (1995) reported the frequency of whistles from 0.8 to 24 kHz.

Inner ear anatomy of this species was described by Ketten (1992). The bottlenose dolphin can typically hear within a broad frequency range of 0.04 kHz to 160 kHz (Au 1993; Turl 1993). The range of highest sensitivity is between 25 and 70 kHz, with peaks in sensitivity occurring at 25 and 50 kHz at threshold levels of 47 and 46 dB re 1 µPa-m, respectively (Nachtigall et al. 2000).

4.3.2.3 Cuvier's beaked whale (*Ziphius cavirostris*)

Stock –California/Oregon/Washington

Population Status—Currently, the best estimate for the California/Oregon/Washington stock is 2,171 (CV = 0.75) individuals (Barlow and Forney 2007).

Distribution—Little is known about the habitat preferences of any beaked whale. Based on current knowledge, beaked whales normally inhabit deep ocean waters (>2,000 m) or continental slopes (200–2,000 m), and only rarely stray over the continental shelf (Pitman 2002). Cuvier's beaked whale generally is sighted in waters >200 m deep, and is frequently recorded at depths >1,000 m (Gannier 2000; MacLeod et al. 2004). They are commonly sighted around seamounts, escarpments, and canyons. MacLeod et al. (2004) reported that Cuvier's beaked whales occur in

deeper waters than Blainville's beaked whales in the Bahamas. Recent data from Ferguson et al. (2006) demonstrated that beaked whales can be found in habitats ranging from continental slopes to abyssal plains. In Hawaii Cuvier's beaked whales showed a high degree of site fidelity in a study spanning 21 years and showed that there was a offshore population and an island associated population (McSweeney et al. 2007). The site fidelity in the island associated population was hypothesized to take advange of the influence of islands on oceanographic conditions that may increase productivity (McSweeney et al. 2007).

Willis and Baird (1998b) reported an incidental catch record for a Cuvier's beaked whale just north of the NWTRC in offshore waters with a bottom depth of approximately 3,300 m. They also reported a Cuvier's beaked whale sighting in waters with a bottom depth of less than 90 m in British Columbia. Tynan et al. (2005) reported an association of beaked whales with strong turbulence caused by rough topography along the slope near Heceta Bank off Oregon.

Waters deeper than 1,000 m are the area of highest utilization for the Cuvier's beaked whale in the Pacific Northwest OPAREA. Areas with water depths between 500 m and 1,000 m are less utilized. Occurrence in waters shallower than 500 m is rare. The majority of the Puget Sound is an area of rare occurrence for this species, except for the deeper waters of the Strait of Juan de Fuca..

Barlow and Forney (2007) estimated Cuvier's beaked whale densities for northern California of 0.003038 individuals per square.

Life History—Little is known of the feeding preferences of Cuvier's beaked whale. They may be mid-water and bottom feeders (Baird et al. 2005b) on cephalopods and, rarely, fish (MacLeod et al. 2003). Additionally, little is known of beaked whale reproductive behavior.

Diving Behavior—Cuvier's beaked whales are generally sighted in waters with a bottom depth greater than about 650 ft (198 m) and are frequently recorded at depths of 3,282 ft (1,000 m) or more (Gannier 2000; MacLeod et al. 2004). They are commonly sighted around seamounts, escarpments, and canyons. In the eastern tropical Pacific Ocean, the mean bottom depth for Cuvier's beaked whales is approximately 11,154 ft (3,400 m), with a maximum depth of over 16,732 ft (5,100 m). (Ferguson 2005). Recent studies by Baird et al. (2006) show that Cuvier's beaked whales dive deeply (maximum of 4,757 ft [1,450 m]) and for long periods (maximum dive duration of 68.7 min) but also spent time at shallow depths. Tyack et al. (2006b) has also reported deep diving for Cuvier's beaked whales with mean depth of 3,510 ft (1,070 m) and mean duration of 58 min. Gouge marks were observed on mud volcanoes on the seafloor at 5,580–6,564 ft (1,700-2,000 m), and Woodside et al. (2006) speculated that they were caused by Cuvier's beaked whales foraging on benthic prey.

Total time at surface (0-2 m) was calculated by subtracting the mean length of deep foraging dives and two shallow duration dives from the total dive cycle (121.4 - 58.0 – 30.4 = 33 min). Total (DFD) time at deepest depth was taken from the vocal phase duration time, as echolocation clicks generally commenced when animals were deepest, and was 32.8 min. The amount of time spent descending and ascending on DFDs was calculated by subtracting the mean Vocal phase duration time from the mean total DFD (58.0 - 32.8 = 25.2 min) and then dividing by five (# of 656 ft (200 m) depth categories between surface and 3,510 ft [1,070 m]) which equals ~five min per 656 ft (200 m). The five-minute value was applied to each 656 ft (200 m) depth category from 1,312-3,510 ft (400-1070 m); for the 7-722 ft (2-220 m) category, the mean length of shallow duration dives was added to the time for descent/ascent (30.4 + 5 = 35.4 min).

Therefore, the depth distribution for Cuvier's beaked whales based on best available information from Tyack et al. (2006b) is: 27% at < 7 ft (2 m), 29% at 7-722 ft (2-220 m), 4% at723-1,312 ft (221-400 m), 4% at 1,313-1,969 ft (401-600 m), 4% at 1,969-2,625 ft (601-800 m), 5% at 1,970-3,510 ft (801-1070 m) and 27% in > 3,510 ft (1070 m).

Acoustics—MacLeod (1999) suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Blaineville's beaked whales echolocation clicks were recorded at frequencies from 20 to 40 kHz (Johnson et al. 2004) and Cuvier's beaked whales at frequencies from 20 to 70 kHz (Zimmer et al. 2005). Soto et al. (2006) reported changes in vocalizations during diving on close approaches of large cargo ships which may have masked their vocalizations. Cuvier's beaked whales only echolocated below 200 m (Tyack et al. 2006a). Echolocation clicks are produced in trains (interclick intervals near 0.4 s and individual clicks are frequency modulated pulses with durations of 200-300 µsec, the center frequency was around 40 kHz with no energy below 20 kHz (Tyack et al. 2006a).

Cook et al. (2006) reported that the Gervais beaked whale (*Mesoplodon europeus*) could hear in the range of 5 to 80 kHz although no measurements were attempted above 80 kHz.

4.3.2.4 Dall's porpoise (*Phocoenoides dalli*)

Stock – California/Oregon/Washington

Population Status—Population size for the Washington/Oregon/California Dall's porpoise stock is estimated to be 57,549 (CV=0.34) individuals (Carretta et al. 2007). No specific data are available regarding trends in population size in California or adjacent waters.

Distribution—Dall's porpoise's range in the eastern North Pacific extends from Alaska south to Baja California (Morejohn 1979). It is probably the most abundant small cetacean in the North Pacific Ocean. Its abundance changes seasonally, probably in relation to water temperature. It is considered to be a cold-water species, and is rarely seen in areas where water temperatures exceed 17°C (Leatherwood et al. 1982). Its distribution shifts southward and nearshore in autumn, especially near the northern Channel Islands, and northward and offshore in late spring (Dohl et al. 1981; Leatherwood et al. 1987; Barlow et al. 1997; Forney and Barlow 1998). Dall's porpoises are found in the NWTRC throughout the year (Forney and Barlow 1998).

Dall's porpoises occur regularly year-round throughout the NWTRC OPAREA and are the most common cetacean in northern Puget Sound and the Strait of Juan de Fuca (Osborne et al. 1988). They are also found in Haro Strait between San Juan Island and Vancouver Island, where tagging studies suggest that Dall's porpoises seasonally move between the Haro Strait area and the Strait of Juan de Fuca or farther west (Hanson et al. 1998). Barlow and Forney (2007) estimated Dall's porpoise densities for Washington and Oregon of 0.151924 individuals per square km and 0.106199 individuals per square km off the northern California coast. Based on predictive spatial habitat models, an overall density estimate of harbor porpoises in the NWTRC was calculated at 0.0970 individuals per square km (DoN 2007a, Appendix B).

Life History— Dall's porpoises feed primarily on small fish and squid (Houck and Jefferson 1999). Groups of Dall's porpoises generally include fewer than 10 individuals and are fluid, probably aggregating for feeding (Jefferson 1990 and 1991; Houck and Jefferson 1999). There is a strong summer calving peak from June through August, and a smaller peak in March (Jefferson 1989). Animals reach sexual maturity at 3.5 to 8 years (Houck and Jefferson 1999).

Diving Behavior—Dall's porpoises in some areas appear to feed preferentially at night on vertically migrating fish and squid associated with the DSL (Houck and Jefferson 1999). Hanson and Baird (1998) provided the first data on diving behavior for this species, an individual tagged for 41 min dove to a mean depth of 33.4 m (S.D. = + 23.9 m) for a mean duration of 1.29 min (S.D. = + 0.84 min).

Total time at the surface was 10.27 min (time between dives minus the dive durations). Dives within 10 m totaled 2.11 min, dives to >60 m totaled 0.4 min, and dives with bottom time between 41 and 60 m totaled 1.83 min. The remaining time can be assumed to be spent diving between 11 and 40 m.

Based on this information, the depth distribution can be estimated as 39% at <1 m, 8% at 1-10 m, 45% at 11-40 m, and 8% at >40 m.

Acoustics—Only short duration pulsed sounds have been recorded for Dall's porpoise (Houck and Jefferson 1999); this species apparently does not whistle often (Richardson et al. 1995). Dall's porpoises produce short-duration (50 to 1,500 μs), high-frequency, narrow band clicks, with peak energies between 120 and 160 kHz (Jefferson 1988). There are no published data on hearing ability of this species.

4.3.2.5 Dwarf and Pygmy sperm whale (*Kogia* spp.)

Stock - California/Oregon/Washington

Population Status—The two species of *Kogia*, dwarf and pygmy sperm whales are distributed widely in the world's oceans, but they are poorly known (Caldwell and Caldwell 1989). Their small size, non-gregarious nature, and cryptic behavior make dwarf sperm and pygmy whales whales difficult to observe. The two species are also difficult to distinguish when sighted at sea, and are often jointly categorized as *Kogia* spp. Dwarf sperm whales within the U.S. Pacific EEZ are each divided into two discrete, non-contiguous areas: (1) Hawaiian waters, and (2) waters off California, Oregon, and Washington (Carretta et al. 2007). The best available estimate of abundance for the California/Oregon/Washington stock of the dwarf sperm whale is unknown (Carretta et al. 2007). Both *Kogia* species have a worldwide distribution in tropical and temperate waters (Jefferson et al. 1993). There is insufficient information available to estimate population size of the dwarf sperm whale off the Pacific coast of the U.S (Carretta et al. 2007).

Distribution— Dwarf and pygmy sperm whales are sighted primarily along the continental shelf edge and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998). However, along the U.S. west coast, sightings of the whales have been rare, although that is likely a reflection of their pelagic distribution and small size rather than their true abundance (Carretta et al. 2002). Several studies have suggested that pygmy sperm whales live mostly beyond the continental shelf edge, whereas dwarf sperm whales tend to occur closer to shore, often over the continental shelf (Rice 1998; Wang et al. 2002; MacLeod et al. 2004). Barros et al. (1998), on the other hand, suggested that dwarf sperm whales might be more pelagic and dive deeper than pygmy sperm whales.

Another suggestion is that the pygmy sperm whale is more temperate, and the dwarf sperm whale more tropical, based at least partially on live sightings at sea from a large database from the eastern tropical Pacific Ocean (Wade and Gerrodette 1993). There, the pygmy sperm whale was not seen in truly tropical waters south of the southern tip of Baja California, but the dwarf sperm whale was common in those waters. This idea is also supported by the distribution of

strandings in South American waters (Muñioz-Hincapié et al. 1998). Also, in the western tropical Indian Ocean, the dwarf sperm whale was much more common than the pygmy sperm whale, which is consistent with this hypothesis (Balance and Pitman 1998).

All eight confirmed stranding records of *Kogia* from Oregon and Washington are of the pygmy sperm whale (Norman et al. 2004). There is one stranding record of the dwarf sperm whale from British Columbia (Nagorsen and Stewart 1983; Willis and Baird 1998a), but this was considered an extralimital stray. Most reports of *Kogia* from the NWTRC probably are pygmy sperm whales.

Barlow and Forney (2007) estimated *Kogia* densities for Washington and Oregon of 0.001232 individuals per square km. Off the northern California coast, their density estimate was 0.000504 individuals per square km, which would suggest approximately

Life History— Both species probably feed on fish and invertebrates that feed on the zooplankton in tropical and temperate waters. There is no information on the breeding behavior of pygmy or dwarf sperm whales

Diving Behavior— *Kogia* feed on cephalopods and, less often, on deep-sea fishes and shrimps (Caldwell and Caldwell 1989; Baird et al. 1996; Willis and Baird 1998; Wang et al. 2002). Willis and Baird (1998) reported that Kogia make dives of up to 25 min. Median dive times of around 11 min have been documented for *Kogia* (Barlow 1999). A satellite-tagged pygmy sperm whale released off Florida was found to make long nighttime dives, presumably indicating foraging on squid in the deep scattering layer (Scott et al. 2001). Most sightings of Kogia are brief; these whales are often difficult to approach and they actively avoid aircraft and vessels (Würsig et al. 1998).

Prey preference, based on stomach content analysis from Atlantic Canada (McAlpine et al. 1997) and New Zealand (Beatson 2007), appears to be mid and deep water cephalopods, crustaceans and fish. There is some evidence that they may use suction feeding and feed at or near the bottom. They may also take advantage of prey undergoing vertical migrations to shallower waters at night (Beatson 2007). In lieu of any other information, Blainville's beaked whale depth distribution data will be extrapolated to pygmy sperm whales as the two species appear to have similar prey preferences and are closer in size than either is to sperm or Cuvier's beaked whales. Blainville's undertakes shallower non-foraging dives in-between deep foraging dives. Blainville's beaked whale depth distribution data, taken from Tyack et al. (2006b) and summarized in greater depth later in this document is: 26% at <2 m, 41% at 2-71 m, 2% at 72-200 m, 4% at 201-400 m, 4% at 401-600 m, 4% at 601-835 m and 19% at >838 m.

Acoustics— No information is available on dwarf sperm whale vocalizations or hearing capabilities. Pygmy sperm whale clicks range from 60 to 200 kHz, with a dominant frequency of 120 kHz (Richardson et al. 1995). An auditory brainstem response study indicates that pygmy sperm whales have their best hearing between 90 and 150 kHz (Ridgway and Carder 2001).

4.3.2.6 Harbor Porpoise (*Phocoena phocoena*)

Stock – Northern California/Southern Oregon, Washington/Oregon Coastal, and Washington Inland

Population Status - Census data suggest a stable population trend. The latest NMFS stock estimates for the three stocks located in the NWTRC area (Northern CA/Southern OR,

Oregon/Washington Coast, and Washington Inland water) are 17,763, 37,745, and 10,682 individuals, respectively (Carretta et al. 2007).

Distribution- Harbor porpoise are generally found in cool temperate to subarctic waters over the continental shelf in both the north Atlantic and North Pacific (Read 1999). This species is seldom found in waters warmer than 17°C (Read 1999) or south of Point Conception (Hubbs 1960; Barlow and Hanan 1995).

Harbor porpoises regularly occur in the NWTRC year-round. Peak abundance is in the fall off northern California (Dohl et al. 1983) and in fall and winter off Oregon and Washington (Green et al. 1992). They occur year-round and breed in the inland waters between Washington and British Columbia (Osborne et al. 1988). Harbor porpoise strandings in Puget Sound and surrounding waters occur most frequently during May, with 70% of strandings between March and June (Osborne 20039; NMFS 2005j).

The harbor porpoise used to be common throughout the Puget Sound (Scheffer and Slipp 1948; Flaherty and Stark 1982). However, most recent sightings within the Puget Sound have been limited to the central portion (Calambokidis et al. 1992; Raum-Suryan and Harvey 1998). There are high harbor porpoise densities north of Orcas Island (Laake, J., NMFS-NMML, pers. comm., 3-6 October 2005).

Life History - Along the coast of Washington, harbor porpoise primarily feed on Pacific herring, market squid, and smelts (Gearin et al. 1994). In most areas, harbor porpoises occur in small groups consisting of just a few individuals. They mature at an earlier age, reproduce more frequently, and live for shorter periods than other toothed whales (Read and Hohn 1995). Calves are born in late spring (Read 1990b; Read and Hohn 1995). Dall's and harbor porpoises appear to hybridize relatively frequently in the Puget Sound area (Willis et al. 2004).

Diving Behavior - Harbor porpoises feed primarily near the seafloor but also within the water column, consuming schooling fish such as herring, capelin, sprat, and silver hake (Reeves et al. 2002). They also prey on squid and octopus, and their seasonal changes in abundance and distribution may be related to the movements of squid (Green et al. 1992).

Acoustics - Harbor porpoise vocalizations include clicks and pulses (Ketten 1998), as well as whistle-like signals (Verboom and Kastelein 1995). The dominant frequency range is 110 to 150 kHz, with source levels of 135 to 177 dB re 1 µPa-m (Ketten 1998). Echolocation signals include one or two low-frequency components in the 1.4 to 2.5 kHz range (Verboom and Kastelein 1995).

A behavioral audiogram of a harbor porpoise indicated the range of best sensitivity is 8 to 32 kHz at levels between 45 and 50 dB re 1 µPa-m (Andersen 1970); however, auditory-evoked potential studies showed a much higher frequency of approximately 125 to 130 kHz with two frequency ranges of best sensitivity (Bibikov 1992). More recent psycho-acoustic studies found the range of best hearing to be 16 to 140 kHz, with a reduced sensitivity around 64 kHz and maximum sensitivity between 100 and 140 kHz (Kastelein et al. 2002).

4.3.2.7 Killer whale (*Orcinus orca*)

Stock - Eastern North Pacific, Offshore

Population Status—Killer whales are segregated socially, genetically, and ecologically into three distinct groups: residents, transients, and offshore animals. Offshore whales do not appear to

mix with the other types of killer whales (Black et al. 1997; Dahlheim et al. 1997). The NMFS population estimate for the eastern North Pacific stock of offshore killer whales is 1,214 individuals (Carretta et al. 2007). There are 422 offshore killer whales estimated to be present in the waters off California, Oregon, and Washington (Carretta et al. 2007).

Distribution—Killer whales from the Eastern North Pacific Southern Offshore Stock, range from Washington to the Southern California Bight and could occur in the NWTRC. Killer whales tend to be seen along the Oregon coast during late April and May and may target gray whale females and calves migrating north. However, based on food type, these probably are transients.

Life History - Diet in the eastern North Pacific is specific to the type of killer whale. The offshore ecotype appears to eat mostly fish (Bigg 1982; Morton 1990; Heise et al. 2003; Herman et al. 2005). Few details are known about the biology of offshore killer whales, but they commonly occur in groups of 20 to 75 individuals (Wiles 2004). There is no information the reproductive behavior of killer whales in this area.

Diving Behavior—The maximum depth recorded for free-ranging killer whales diving off British Columbia is about 864 ft (263 m) (Baird et al. 2005). On average, however, for seven tagged individuals, less than 1 percent of all dives examined were to depths greater than about 100 ft (30 m) (Baird et al. 2003). The longest duration of a recorded dive from a radio-tagged killer whale was 17 min (Dahlheim and Heyning 1999).

"Transient" stocks of killer whales feed on other marine mammals, including other whales, pinnipeds (e.g., London 2006) and sea otters (e.g., Estes et al. 1998). Diving studies on killer whales have been undertaken mainly on "resident" (fish-eating) killer whales in Puget Sound and may not be applicable across all populations of killer whales. Diving is usually related to foraging, and mammal-eating killer whales may display different dive patterns. Killer whales in one study (Baird et al. 2005b) dove as deep as 866 ft (264 m), and males dove more frequently and more often to depths > 328 ft (100 m) than females, with fewer deep dives at night. Dives to deeper depths were often characterized by velocity bursts which may be associated with foraging or social activities.

Using best available data from Baird et al. (2003a), it would appear that killer whales spend ~4% of time at depths > 100 ft (30 m) and 96% of time at depths 0-100 ft (0-30 m).

Acoustics—The killer whale produces a wide variety of clicks and whistles, but most of its sounds are pulsed and at 1 to 6 kHz (Richardson et al. 1995). The peak to peak source levels of echolocation signals range between 195 and 224 dB re 1 μPa-m (Au et al. 2004). The source level of social vocalizations ranges between 137 to 157 dB re 1 μPa-m (Veirs 2004). Acoustic studies of resident killer whales in British Columbia have found that there are dialects, in their highly stereotyped, repetitive discrete calls, which are group-specific and shared by all group members (Ford 2002). These dialects likely are used to maintain group identity and cohesion, and may serve as indicators of relatedness that help in the avoidance of inbreeding between closely related whales (Ford 2002). Dialects also have been documented in killer whales occurring in northern Norway, and likely occur in other locales as well (Ford 2002). The killer whale has the lowest frequency of maximum sensitivity and one of the lowest high frequency hearing limits known among toothed whales (Szymanski et al. 1999). The upper limit of hearing is 100 kHz for this species. The most sensitive frequency, in both behavioral and in auditory brainstem response audiograms, has been determined to be 20 kHz (Szymanski et al. 1999).

4.3.2.8 Killer whale, Transient (*Orcinus orca*)

Stock – Eastern North Pacific, Transient

Population Status—The population estimate for the Eastern North Pacific Stock of transient killer whales is 346 (Carretta et al. 2007) and along the coast of California 105 killer whales have been identified by Forney et al. 2000).

Distribution— Transient killer whales in the eastern North Pacific spend most of their time along the outer coast, but visit Hood Canal and Puget Sound in search of harbor seals, sea lions, and other prey. Transient occurrence in inland waters appears to peak during August and September (Morton 1990; Baird and Dill 1995; Ford and Ellis 1999) which is the peak time for harbor seal pupping, weaning, and post-weaning (Baird and Dill 1995).

Life History—Transient killer whales show greater variability in habitat use, with some groups spending most of their time foraging in shallow waters close to shore while others hunt almost entirely in open water (Heimlich-Boran 1988; Felleman et al. 1991; Baird and Dill 1995; Matkin and Saulitis 1997). Transient killer whales feed on marine mammals and some seabirds, but apparently no fish (Morton 1990; Baird and Dill 1996; Ford et al. 1998; Ford and Ellis 1999; Ford et al. 2005). Transient killer whales travel in small, matrilineal groups, but they typically contain fewer than 10 animals and their social organization generally is more flexible than in residents (Morton 1990; Ford and Ellis 1999). These differences in social organization probably relate to differences in foraging (Baird and Whitehead 2000). There is no information the reproductive behavior of killer whales in this area.

Diving Behavior—Diving behavior is assumed to be similar to that of the offshore stock but may feed on different prey items.

Acoustics—The acoustic abilities of transient killer whales is assumed to be similar to the population of killer whales described in the above section on the killer whale offshore stock. In contrast to resident whales, transient killer whales appear to use passive listening as a primary means of locating prey, call less often, and use high-amplitude vocalizations only when socializing, communicating over long distances, or after a successful attack. This probably results from the ability of other marine mammal species (their prey) to "eavesdrop" on killer whale sounds (Barrett-Lennard et al. 1996; Deecke et al. 2005; Saulitis et al. 2005).

4.3.2.9 Mesoplodont Beaked Whales (*Mesoplodon* sp.)

Stock – California/Oregon, Washington

Population Status - Census data and life history are too limited to suggest a population trend for individual species. Until better methods are developed for distinguishing the different mesoplodont species from one another, the management unit is defined to include all mesoplodont populations. Currently, a population estimate of 1,024 (CV = 0.77) individuals for all mesoplodont species was calculated by Carretta et al. (2007) for the California/Oregon/Washington stock.

The Hubbs' beaked whale (*Mesoplodon carlhubbsi*) appears to be restricted to the North Pacific Ocean (Mead et al. 1982; Houston 1990; MacLeod et al. 2006). Nearly all records have involved strandings along the west coast of North America and in Japan, with one live sighting made La Jolla, California (Hubbs 1946; Mead et al. 1982). There have also been several sightings in relatively nearshore waters of the Pacific Northwest, and MacLeod et al. (2006) speculated that

the distribution might actually be continuous across the North Pacific between about 30° and 45°N. The Stejneger's beaked whale (*M. stejnegeri*) species appears to prefer cold-temperate and sub-polar waters (Loughlin and Perez 1985; MacLeod et al. 2006). It is found in the North Pacific from southern California to the Bering Sea and, on the west side of the Pacific basin, as far south as the Miyagi Prefecture, Japan (Loughlin and Perez 1985; MacLeod et al. 2006).

Distribution - World-wide, beaked whales normally inhabit continental slope and oceanic waters that are deeper than 656 ft (200 m) (Waring et al. 2001; Cañadas et al. 2002; Pitman 2002; MacLeod et al. 2004; Ferguson et al. 2006; MacLeod and Mitchell 2006). Occurrence often has been linked to the continental slope, canyons, escarpments, and oceanic islands (MacLeod and D'Amico 2006). For example, Tynan et al. (2005) reported an association of beaked whales with strong turbulence caused by rough topography along the slope near Heceta Bank off the Oregon coast. Beaked whales are only occasionally reported in waters over the continental shelf (Pitman 2002).

Life History - This species may be both a mid-water and bottom feeder (Baird et al. 2005b) on squid and fish (Mead et al. 1982). They occur alone or in groups of up to 15 (MacLeod and D'Amico 2006), and probably calve in the summer (Mead et al. 1982; Willis and Baird 1998b).

Diving Behavior - Analysis of stomach contents from captured and stranded individuals suggests that beaked whales are deep-diving animals, feeding by suction (Heyning and Mead 1996). Another species of beaked whales, the Baird's beaked whale, feeds mainly on benthic fishes and cephalopods, but occasionally on pelagic fish such as mackerel, sardine, and saury (Kasuya, 2002; Walker et al. 2002; Ohizumi et al. 2003). Baird et al. (2006) reported on the diving behavior of four Blaineville's beaked whales (*M. densirostris*) off the west coast of Hawaii. The four beaked whales foraged in deep ocean areas (2,270-9,855ft [690-3,000 m]) with a maximum dive to 4,619 ft (1,408 m). Dives ranged from at least 13 min (lost dive recorder during the dive) to a maximum of 68 min (Baird et al. 2006). Tyack et al. (2006b) reported a mean depth of 2,740 ft (835 m) and mean duration of 46.5 min for Baird's beaked whales.

Acoustics - Sounds recorded from beaked whales include whistles and pulsed sounds (clicks) (Johnson et al. 2004; Madsen et al. 2005; MacLeod and D'Amico 2006). Whistle frequencies are about 2 to 12 kHz, while pulsed sounds range in frequency from 300 Hz to 135 kHz, although higher frequencies might not have been recorded because of equipment limitations (MacLeod and D'Amico 2006). Vocalizations recorded from two juvenile Hubbs' beaked whales consisted of low and High-frequency click trains ranging in frequency from 300 Hz to 80 kHz and whistles with a frequency range of 2.6 to 10.7 kHz and duration of less than half a second (Lynn and Reiss 1992; Marten 2000).

There are no hearing data available for the beaked whale. A stranded juvenile Gervais' beaked whale (*M. europaeus*). was found to be most sensitive to high-frequency signals between 40 and 80 kHz but produced smaller evoked potentials to 5 kHz (Cook et al. 2006). Beaked whale ears are predominantly adapted to hear ultrasonic frequencies and, based on the anatomy of the ears, may be more sensitive than other cetaceans to low-frequency sounds (MacLeod 1999).

4.3.2.10 Northern right whale dolphin (*Lissodelphis borealis*)

Stock - California/Oregon/Washington

Population Status—There are no available data regarding trends in population size in California or adjacent waters. Population size of the California/Oregon/Washington Stock is estimated to be 15,305 (CV=0.32) individuals (Carretta et al. 2007).

Distribution—This species is endemic to the North Pacific Ocean, and is found primarily in temperate (8–19ºC) continental shelf and slope waters (Leatherwood and Walker 1979; Barlow et al. 1997). Northern right whale dolphins occur in the NWTRC year-round, but their abundance and distribution vary seasonally. They occur off Oregon and Washington except in winter; peak abundance off these coasts occurs along the continental slope in fall (Green et al. 1992). This species is most abundant off central and northern California in nearshore waters in winter (Dohl et al. 1983). Barlow and Forney (2007) estimated northern right whale dolphin densities for Washington and Oregon of 0.019373 individuals per square km and 0.006401 individuals per square km off the northern California coast. Based on predictive spatial habitat models, the overall density estimate of northern right ehale dolphins in the NWTRC is 0.0124 individuals per square km (DoN 2007a, Appendix B).

Life History— The diet primarily includes squid and mesopelagic fish (Leatherwood and Walker 1979; Jefferson et al. 1994). In the cool temperate to subarctic waters of the North Pacific Ocean, distribution usually is from 30°N to 55°N and 145°W to 118°E. (Leatherwood and Walker 1979). Seasonal inshore-offshore and north-south movements are presumably related to prey availability, including in abundance of market squid, *Loligo opalescens,* a major prey item (Leatherwood and Walker 1979).

Sexual maturity occurs at about 10 years (Ferrero and Walker 1993). Although calving seasonality is unknown, small calves are seen in winter and early spring (Jefferson et al. 1994).

Diving Behavior—There is no information on the diving behavior of northern right whale dolphins. They feed on small fish, especially lanternfish and squid (Lipsky 2002), and are believed to take advantage of the deep scattering layer around 656 ft (200 m). Based on the lack of specific information, spinner dolphin depth distribution data will be extrapolated to northern right whale dolphins. Studies on spinner dolphins in Hawaii have been carried out using active acoustics (fish-finders) (Benoit-Bird and Au 2003). These studies show an extremely close association between spinner dolphins and their prey (small, mesopelagic fishes). Mean depth of spinner dolphins was always within 33 ft (10 m) of the depth of the highest prey density. These studies have been carried out exclusively at night, as stomach content analysis indicates that spinners feed almost exclusively at night when the deep scattering layer moves toward the surface bringing potential prey into relatively shallower (0-1,300 ft [0-400 m]) waters. Prey distribution during the day is estimated at 1,300-2,300 ft (400-700 m).

Based on these data, the following are very rough order estimates of time at depth: daytime: 100% at 0-165 ft (0-50 m); nighttime: 100% at 0-1,300 ft (0-400 m).

Acoustics—Clicks with high repetition rates and whistles have been recorded from animals at sea (Fish and Turl 1976; Leatherwood and Walker, 1979). Maximum source levels were approximately 170 dB 1 μPa-m (Fish and Turl 1976). Rankin et al. (2007) reported the mean frequency of individual echolocation clicks were 31.3 kHz (Range of 23 – 41 kHz; SD = 3.7 kHz). There is no published data on the hearing abilities of this species.

4.3.2.11 Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)

Stock - California/Oregon/Washington

Population Status—The Pacific white-sided dolphin is not listed under the ESA, and the California/Oregon/Washington Stock is not considered depleted or strategic under the MMPA. No population trends have been observed in California or adjacent waters. Size of the California/Oregon/Washington Stock is estimated to be 25,233(CV=0.25) individuals (Carretta et al. 2007).

Distribution—The Pacific white-sided dolphin is most common in waters over the continental shelf and slope. Sighting records and captures in pelagic driftnets indicate that this species occurs in oceanic waters well beyond the shelf and slope (Leatherwood et al. 1984; Ferreo and Walker 1999). The Pacific white-sided dolphin occurs across temperate Pacific waters, to latitudes as low as (or lower than) 38°N, and northward to the Bering Sea and coastal areas of southeast Alaska (Leatherwood et al. 1984). Surveys suggest a seasonal north-south movement of Pacific white-sided dolphins in the eastern North Pacific, with animals found primarily off California during the colder water months and shifting northward into Oregon and Washington as water temperatures increase during late spring and summer (Green et al. 1992; Forney 1994; Carretta et al. 2007).

Barlow and Forney (2007) estimated Pacific white-sided dolphin densities for Washington and Oregon of 0.024823 individuals per square km and 0.016029 individuals per square km off the northern California coast. Based on predictive spatial habitat models, the overall density estimates of Pacific white-sided dolphins in the NWTRC was calculated at 0.0441 individuals per square km (DoN 2007a, Appendix B).

Life History - The diet in the eastern North Pacific includes cephalopods and fish (Schwartz et al. 1992; Black 1994; Heise 1997a; Brownell et al. 1999; Morton 2000), and includes salmonids off Washington (Stroud et al. 1981). In this gregarious species, group sizes range from tens to thousands of dolphins (Leatherwood et al. 1984). They frequently aggregate with Risso's and northern right whale dolphins (Brownell et al. 1999). Calving peaks from June through August (Heise 1997b).

Diving Behavior— Studies on diving by this species have not been undertaken. Pacific white-sided dolphins in the eastern North Pacific feed primarily on epipelagic fishes and cephalopods (e.g., Schwartz et al. 1992; Black 1994; Heise 1997; Brownell et al. 1999; Morton 2000). Leatherwood (1975) observed Pacific white-sided dolphins and California sea lions feeding together on anchovies off southern California. This does not appear to be a deep-diving species. Based on feeding habits, Fitch and Brownell (1968) inferred that Pacific white-sided dolphins dive to at least 395 ft (120 m). The majority of foraging dives last less than 15 to 25 sec (Black 1994; Heise 1997). Pacific white-sided dolphins are generalist feeders (van Waerebeek and Wursig, 2002). Satellite tag studies of a rehabilitated related species (Lagenorhynchus acutus) in the Gulf of Maine indicated that nearly all time was spent in waters < 328 ft (100 m) total depth with largely directed movement (Mate et al. 1994). Another related species, Lagenorhynchus obscurus, was observed feeding in two circumstances; at night to 430 ft (130 m) depth to take advantage of the deep scattering layer closer to the surface and during the day in shallower depths (< 215 ft [65 m]) where they fed on schooling fish (Benoit-Bird et al. 2004).

In lieu of the lack of other data available for this species, the following are very rough estimates of time at depth: daytime - 100% at 0-215 ft (0-65 m); night time – 100% at 0-430 ft (0-130 m).

Acoustics—Vocalizations produced by Pacific white-sided dolphins include whistles and clicks. Whistles are in the frequency range of 2 to 20 Hz (Richardson et al. 1995). Peak frequencies of the pulse trains for echolocation fall between 50 and 80 kHz; the peak amplitude is 170 dB re 1μPa-m (Fahner et al. 2004). Tremel et al. (1998) measured the underwater hearing sensitivity of the Pacific white-sided dolphin from 75 Hz through 150 kHz. The greatest sensitivities were from 4 to 128 kHz. Below 8 Hz and above 100 kHz, this dolphin's hearing was similar to that of other toothed whales.

4.3.2.12 Risso's dolphin (*Grampus griseus*)

Stock – California/Oregon/Washington

Population Status— The Risso's dolphin is relatively common in most Pacific coast nearshore waters along the U.S. The population estimate of the California/Oregon/Washington stock is 12,093 (CV=0.24) individuals (Carretta et al. 2007).

Distribution— Risso's dolphins are distributed world-wide in tropical and warm-temperate waters. Off the U.S. West coast, Risso's dolphins are commonly seen on the shelf in the Southern California Bight and in slope and offshore waters of California, Oregon and Washington. A comprehensive study of the distribution of Risso's dolphin in the Gulf of Mexico found that they used the steeper sections of the upper continental slope in waters 1,150–3,200 ft (350–975 m) deep (Baumgartner 1997). Inland water stranding records for this species are from March 1975 in Discovery Bay in the eastern Strait of Juan de Fuca (Everitt et al. 1979) and near Port Angeles in October 1987 (Osborne et al. 1988).

Barlow and Forney (2007) estimated Risso's dolphin densities for Washington and Oregon of 0.013222 individuals per square km and 0.004014 individuals per square km off the northern California coast.

Life History - Cephalopods are the primary prey (Clarke 1996). In this social species, groups usually are about 30 individuals, but can include several hundred (Kruse et al. 1999) or several thousand animals (Jefferson, T.A., NMFS-SWFSC, pers. comm., 14-18 March 2005), including Pacific white-sided dolphins and northern right whale dolphins (Kruse et al. 1999). There is no information on the breeding behavior in this area.

Diving Behavior—There are no depth distribution data for this species. They may remain submerged on dives for up to 30 min (Kruse et al. 1999). Cephalopods are the primary prey (Clarke 1996). They are primarily squid eaters and feeding is presumed to take place at night. A study undertaken in the Gulf of Mexico demonstrated that Risso's are distributed non-uniformly with respect to depth and depth gradient (Baumgartner 1997), utilizing mainly the steep sections of upper continental slope bounded by the 1,150 ft (350 m) and 3,200 ft (975 m) isobaths. That data agrees closely with Blanco et al. (2006), who collected stomach samples from stranded Risso's dolphins in the western Mediterranean. Their results indicate that, based on prey items, Risso's feed on the middle slope at depths ranging from 2,000-2,600 ft (600-800 m). Stomach content analysis from three animals elsewhere in the Mediterranean indicated that Risso's fed on species that showed greater vertical migrations than those ingested by striped dolphins (Ozturk et al. 2007).

In lieu of depth distribution information or information on shape of dives, the following are very rough estimates of time at depth based on habitat and prey distribution: 50% at < 165 ft (50 m), 15% at 166-656 ft (51-200 m), 15% at 657-1,312 ft (201-400 m), 10% at 1,313-2,000 ft (401-600 m) and 10% at > 2,000 ft (600 m).

Acoustics—Risso's dolphin vocalizations include broadband clicks, barks, buzzes, grunts, chirps, whistles, and simultaneous whistle and burst-pulse sounds (Corkeron and Van Parijs 2001). The combined whistle and burst pulse sound appears to be unique to Risso's dolphin (Corkeron and Van Parijs 2001). Corkeron and Van Parijs (2001) recorded five different whistle types, ranging in frequency from 4 to 22 kHz. Broadband clicks had a frequency range of 6 to greater than 22 kHz. Low-frequency narrowband grunt vocalizations had a frequency range of 0.4 to 0.8 kHz. A recent study established empirically that Risso's dolphins echolocate; estimated peak to peak source levels were up to 216 dB re 1 µPa-m at frequencies of 27.4-104.7 kHz (Philips et al. 2003).

The range of hearing in Risso's dolphins is 1.6-122.9 kHz with maximum sensitivity occurring between 8 and 64 kHz (Nachtigall et al. 1995).

4.3.2.13 Short-beaked common dolphin (*Delphinus delphis*)

Stock – California/Oregon/Washington

Population Status—The short-beaked common dolphin is the most abundant cetacean off California (Dohl et al. 1981; Forney et al. 1995; Carretta et al. 2007). The single current management unit for the short-beaked common dolphin in this area is a California/Oregon/Washington Stock with a population estimate of 487,622 (CV = 0.26) individuals (Carretta et al. 2007). The abundance of common dolphins varies seasonally but may be increasing in California with a northward shift in the population (Heyning and Perrin 1994; Barlow et al. 1997; Forney 1997). The short beaked common dolphin is not listed as endangered under the ESA or as depleted or strategic under the MMPA.

Distribution— The short-beaked common dolphin is found in coastal and offshore waters along the eastern Pacific coast from Peru to Vancouver Island. They are widely distributed to 300 nm (556 km) offshore (Carretta et al. 2002). Common dolphins are usually found in large groups of hundreds to thousands of individuals and are often associated with other marine mammal species (American Cetacean Society 2004). Along the U.S. west coast, the short-beaked common dolphins' distribution overlaps with that of the long-beaked common dolphin. During summer and fall, short-beaked common dolphins primarily occur along the outer coast in waters deeper than 656 ft (200 m), south of 42°N and to a lesser extent in water depths between 328 ft (100 m) and 656 ft (200 m) south of 42°N, and seaward of the 328 ft (100 m) water depth north of 42°N. In winter and spring, animals typically stay south of the 13°C isotherm. There is a rare occurrence for this species in waters cooler than 12°C and within the Puget Sound.

Barlow and Forney (2007) estimated short-beaked common dolphin densities for Washington and Oregon of 0.014137 individuals per square km and 0.259357 individuals per square km off the northern California coast. Based on predictive spatial habitat models, the overall density estimate of short-beaked common dolphins in the NWTRC is 0.1570 individuals per square km (DoN 2007a, Appendix B).

Life History – The diet of the short-beaked common dolphin primarily is fish and cephalopods. Group size ranges from several dozen to more than 10,000 (Jefferson et al. 1993). Peak calving is in spring and early summer (Forney 1994).

Diving Behavior—Limited direct measurements but dives to > 656 ft (200 m) possible, but most in the range of 30-165 ft (9-50 m) based on a study on one tagged individual tracked off San Diego (Evans 1971, 1994). Common dolphins feed on small schooling fish as well as squid and crustaceans, and varies by habitat and location. They appear to take advantage of the deep scattering layer at dusk and during early night-time hours, when the layer migrates closer to the water surface, as several prey species identified from stomach contents are known to vertically migrate (e.g., Ohizumi et al. 1998; Pusineri et al. 2007). Perrin (2002b) reports foraging dives to 656 ft (200 m), but there have been no detailed studies of diving behavior.

Based on this limited information, depth distribution is estimated as: 100% at 0-656 ft (0-200 m).

Acoustics—Recorded Delphinus vocalizations include whistles, chirps, barks, and clicks (Ketten 1998). Clicks and whistles have dominant frequency ranges of 23 to 67 kHz and 0.5 to 18 kHz, respectively (Ketten 1998). Maximum source levels of clicks were approximately 180 dB 1 µPa-m (Fish and Turl 1976). Oswald et al. (2003) found that short-beaked common dolphins in the eastern tropical Pacific have whistles with a mean frequency range of 6.3 kHz, mean maximum frequency of 13.6 kHz, and mean duration of 0.8 sec. Popov and Klishin (1998) recorded auditory brainstem responses from a common dolphin. The audiogram was U-shaped with a steeper high-frequency branch. The audiogram bandwidth was up to 128 kHz at a level of 100 dB above the minimum threshold. The minimum thresholds were observed at frequencies of 60 to 70 kHz.

4.3.2.14 Short-finned pilot whale (*Globicephala macrorhynchus*)

Stock – California/Oregon/Washington

Population Status—The short-finned pilot whale is not listed under the ESA. However, the California/Oregon/Washington Stock is considered strategic under the MMPA because the average human-caused mortality may not be sustainable (Barlow et al. 1997). Population size for the California/Oregon/Washington Stock is 245 (CV=0.97) individuals (Carretta et al. 2007).

Distribution— Worldwide, pilot whales usually are found over the continental shelf break, in slope waters, and in areas of high topographic relief, but movements over the continental shelf and close to shore at oceanic islands can occur (Mignucci-Giannoni 1998; Gannier 2000; Olson and Reilly 2002). The short-finned pilot whale is found in tropical to warm-temperate seas. It usually does not range north of 50°N or south of 40°S (Jefferson et al. 1993). The range of the short-finned pilot whale appears to be expanding to fill the former range of the long-finned pilot whale (Bernard and Reilly 1999), which apparently has been extirpated from the North Pacific (Kasuya 1975).

Along the west coast of North America, sightings of short-finned pilot whales north of Point Conception are uncommon (Everitt et al. 1979; Osborne et al. 1988; Forney 1994). Baird and Stacey (1993) and Stacey and Baird (1993) reviewed occurrence records in British Columbia waters and recommended that it be considered rare there, occurring in most years, but with only a few records per year. Norman et al. (2004) found that most stranding events for this species occurred during or within a year of an El Niño. Occurrence records for the OPAREA are

primarily during the warmer months (Fiscus and Niggol 1965; Pike and MacAskie 1969; Everitt et al. 1979; Baird and Stacey 1993).

Life History - Distribution and seasonal inshore/offshore movements probably coincide closely with the abundance of squid, their preferred prey (Hui 1985; Waring et al. 1990; Waring and Finn 1995; Bernard and Reilly 1999). Pilot whales are very social and may travel in groups of several to hundreds of animals, often with other cetaceans (Bernard and Reilly 1999; Gannier 2000). They appear to live in relatively stable, female-based groups (Jefferson et al. 1993). Sexual maturity occurs at 9 years for females and 17 years for males (Bernard and Reilly 1999). The mean calving interval is 4 to 6 years (Bernard and Reilly 1999). Calving peaks in the northern hemisphere vary by stock (Jefferson et al. 1993).

Diving Behavior—Pilot whales are deep divers; the maximum dive depth measured is about 3,186 ft (971 m) (Baird et al. 2002). Short-finned pilot whales feed on squid and fish. Stomach content analysis of pilot whales in the Southern California Bight consisted entirely of cephalopod remains (Sinclair 1992). The most common prey item identified by Sinclair (1992) was *Loligo opalescens*, which has been documented in spawning concentrations at depths of 66-180 ft (20-55 m). Stomach content analysis from the closely related long-finned pilot whale (*Globicephala melas*) from the U.S mid-Atlantic coast demonstrated preference for cephalopods as well as a relatively high diversity of prey species taken (Gannon et al. 1997). Stomach content analysis from *G. melas* off New Zealand did not show the same diversity of prey (Beatson et al. 2007a) which indicates that pilot whales may differ significantly in prey selection based on geographic location. Pilot whales feed primarily on squid, but also take fish (Bernard and Reilly 1999). Pilot whales are not generally known to prey on other marine mammals; however, records from the eastern tropical Pacific suggest that the short-finned pilot whale does occasionally chase, attack, and may eat dolphins during fishery operations (Perryman and Foster 1980), and they have been observed harassing sperm whales in the Gulf of Mexico (Weller et al. 1996). A diving study on *G. melas* also showed marked differences in daytime and nighttime diving in studies in the Ligurian Sea (Baird et al. 2002), but there was no information on percentage of time at various depth categories. A study following two rehabilitated and released long-finned pilot whales provides a breakdown of percentage of time at depth distribution for two whales (Nawojchik et al. 2003), although this data may be skewed due to the unique situation. Heide-Jorgensen et al. (2002) studied diving behavior of long-finned pilot whales near the Faroe Islands in the north Atlantic. Most diving activity occurred at depth of less than 118 ft (36 m) and >90% of dives were within 39-56 ft (12-17 m). Based on this information, the following are estimates of time at depth for both species of pilot whale: 60% at < 23 ft (7 m), 36% at 23-56 ft (7-17 m) and 4% at 57-2,717 ft (18-828 m).

Acoustics—Short-finned pilot whale whistles and clicks have a dominant frequency range of 2 to 14 kHz and a source level of 180 dB re 1 µPa-m for whistles (Fish and Turl 1976; Ketten 1998). There are no published hearing data available for this species.

4.3.2.15 Striped dolphin (*Stenella coeruleoalba*)

Stock – California/Oregon/Washington

Population Status—The striped dolphin is not listed as endangered under the ESA, and the California/Oregon/Washington Stock is not considered to be depleted or strategic under the MMPA. The best estimate of the size of the California/Oregon/Washington Stock is 23,883 (CV=0.44) individuals (Carretta et al. 2007).

Distribution—Striped dolphins have a cosmopolitan distribution in tropical to warm temperate waters (Perrin et al. 1994a). Their preferred habitat seems to be deep water (Davis et al. 1998) along the edge and seaward of the continental shelf, particularly in areas influenced by warm currents (Waring et al. 2002). This species is well documented in both the western and eastern Pacific off the coasts of Japan and North America (Perrin et al. 1994); the northern limits are the Sea of Japan, Hokkaido, Washington state, and along roughly 40°N across the western and central Pacific (Reeves et al. 2002). The striped dolphin in the Pacific Northwest OPAREA is typically found in coast waters warmer than 15.5°C and deeper than 328 ft (100 m). Striped dolphins rarely occur in waters cooler than 15°C on the outer coast and throughout the Puget Sound.

Barlow and Forney (2007) estimated striped dolphin densities for Washington and Oregon of 0.0000145 individuals per nm^2 (0.0000497 per km^2) and 0.004564 individuals per nm^2 (0.015653 per km^2 off the northern California coast.

Life History - Striped dolphins feed on fish and squid (Perrin et al. 1994) in pelagic or benthopelagic zones along the continental slope or just beyond in oceanic waters. Striped dolphins are typically found in groups of 100 and 500, although they sometimes gather in the thousands. Sexual maturity occurs between 5 and 15 years of age (Archer II and Perrin 1999). Off Japan, where their biology has been best studied, there are summer and winter calving peaks (Perrin et al. 1994).

Diving Behavior—Striped dolphins often feed in pelagic or benthopelagic zones along the continental slope or just beyond oceanic waters. A majority of the prey possess luminescent organs, suggesting that striped dolphins may be feeding at great depths, possibly diving to about 654 to 2,298 ft (200 to 700 m) to reach potential prey (Archer and Perrin 1999). Striped dolphins may feed at night, in order to take advantage of the deep scattering layer's diurnal vertical movements. Small, mid-water fishes (in particular, myctophids or lanternfish) and squids are the dominant prey (Perrin et al. 1994).

Acoustics—Striped dolphin whistles range from 6 to at least 24 kHz, with dominant frequencies ranging from 8 to 12.5 kHz (Richardson et al. 1995). The striped dolphin's range of most sensitive hearing (defined as the frequency range with sensitivities within 10 dB of maximum sensitivity) was determined to be 29 to 123 kHz using standard psycho-acoustic techniques; maximum sensitivity occurred at 64 kHz (Kastelein et al. 2003). Hearing ability became less sensitive below 32 kHz and above 120 kHz (Kastelein et al. 2003).

4.3.3 Pinnipeds

4.3.3.1 California Sea Lion (*Zalophus californianus*)

Stock – United States

Population Status— The U.S. stock of California sea lions uses the Pacific Northwest OPAREA and Puget Sound. The estimated stock is 238,000 and the minimum population size of this stock is 141,842 individuals (Carretta et al. 2007). This number is from counts during the 2001 breeding season of animals that were ashore at the four major rookeries in southern California and at haulout sites north to the Oregon/California border. Sea lions that were at sea or were hauled out at other locations were not counted (Carretta et al. 2007).

Distribution— During the summer, California sea lions breed on islands from the Gulf of California to the Channel Islands and seldom travel more than about 27 nm (50 km) from the

islands (Bonnell et al. 1983). The primary rookeries are located on the California Channel Islands of San Miguel, San Nicolas, Santa Barbara, and San Clemente (Le Boeuf and Bonnell 1980; Bonnell and Dailey 1993). Their distribution shifts to the northwest in fall and to the southeast during winter and spring, probably in response to changes in prey availability (Bonnell and Ford 1987). In the non-breeding season, adult and subadult males migrate northward along the coast to central and northern California, Oregon, Washington, and Vancouver Island, are occasionally sighted hundreds of kilometers offshore (Jefferson et al. 1993), and return south the following spring (Mate 1975; Bonnell et al. 1983). Females and juveniles tend to stay closer to the rookeries (Bonnell et al. 1983).

They also enter bays, harbors, and river mouths (Jefferson et al. 1993) and often haul out on man-made structures such as piers, jetties, offshore buoys, and oil platforms (Riedman 1990). California sea lions in the Puget Sound haul out on log booms and U.S. Navy submarines, and are often seen rafted off river mouths (Jeffries et al. 2000; DoN 2001 b).

California sea lions occur found in the NWTRC throughout the year but are most abundant between September and June during the non-breeding season (Bonnell et al. 1983; NMFS 1997b). Most of the animals in the NWTRC are large, adult males that migrate along the coast, usually within 20 km from the shore (Bonnell et al. 1992). They are mostly sighted along the shelf break and continental slope (Bonnell et al. 1983; Calambokidis et al. 2004b) or at haulout sites along the coasts and inland waters. Periods of use and main haulout sites are as follows (NMFS 1997b; Gearin et al. 2001; DeLong, R., NMML, pers. comm., 3 May 2006):

- In Washington waters, they are present from around September through May and are concentrated in the Puget Sound (NMFS 1997b). Main haulout sites include Cape Alava.

- They are present along the coast of Oregon from October to April (NMFS 1997b). Main haulout sites include the Columbia River (South Jetty), Cascade Head, Cape Arago, and Orford and Rogue Reefs.

- They utilize the northern coast of California mainly during May and June, and September and October (Bonnell et al. 1983). Main haulout sites include St. George Reef, Castle Rock, and Farallon and Año Nuevo Islands

The warm season density estimate for California sea lions is 0.00092 and for the cold season the density estimate is 0.032 sea lions per square kilometer (DoN 2007a, Appendix B).

Life history- Survey data from 1975 to 1978 were analyzed to describe the seasonal shifts in the offshore distribution of California sea lions (Bonnell and Ford 1987). During summer, the highest densities were found immediately west of San Miguel Island. During autumn, peak densities of sea lions were centered on Santa Cruz Island. During winter and spring, peak densities occurred just north of San Clemente Island. The seasonal changes in the center of distribution were attributed to changes in the distribution of the prey species. If California sea lion distribution is determined primarily by prey abundance, these same areas might not be the center of sea lion distribution every year.

The distribution and habitat use of California sea lions vary with the sex of the animals and their reproductive phase. Adult males haul out on land to defend territories and breed from mid-to-late May until late July. Individual males remain on territories for 27–45 days without going to sea to feed. During August and September, after the mating season, the adult males migrate northward to feeding areas as far away as Washington (Puget Sound) and British Columbia

(Lowry et al. 1992). They remain there until spring (March–May), when they migrate back to the breeding colonies. Distribution of immature California sea lions is less well known, but some make northward migrations that are shorter in length than the migrations of adult males (Huber 1991). However, most immature seals are presumed to remain near the rookeries (Lowry et al. 1992). Adult females remain near the rookeries throughout the year. Most births occur from mid-June to mid-July (peak in late June).

Diving Behavior - Over one third of the foraging dives by breeding females are 1–2 min in duration; 75% of dives are <3 min, and the longest recorded dive was 9.9 min (Feldkamp et al. 1989). Approximately 45% of dives were to depths of 66–160 ft (20–50 m) and the maximum depth of a dive was 900 ft (274 m) (Feldkamp et al. 1989). Much of the variation in duration and depth of dives appears to be related to sea lions foraging on vertically-migrating prey. Longer dives to greater depths typically occur during the day, and shorter dives to shallower depths typically occur at night, when prey migrate toward the surface (Feldkamp et al. 1989).

Acoustics—In-air, California sea lions make incessant, raucous barking sounds; these have most of their energy at less than 2 kHz (Schusterman et al. 1967; Richardson et al. 1995). Males vary both the number and rhythm of their barks depending on the social context; the barks appear to control the movements and other behavior patterns of nearby conspecifics (Schusterman 1977). Females produce barks, squeals, belches, and growls in the frequency range of 0.25 to 5 kHz, while pups make bleating sounds at 0.25 to 6 kHz (Richardson et al. 1995). California sea lions produce two types of underwater sounds: clicks (or short-duration sound pulses) and barks (Schusterman et al. 1966, 1967; Schusterman and Baillet 1969). All underwater sounds have most of their energy below 4 kHz (Schusterman et al. 1967).

The range of maximal sensitivity underwater is between 1 and 28 kHz (Schusterman et al. 1972). Functional underwater high frequency hearing limits are between 35 and 40 kHz, with peak sensitivities from 15 to 30 kHz (Schusterman et al. 1972). The California sea lion shows relatively poor hearing at frequencies below 1,000 Hz (Kastak and Schusterman 1998). Peak sensitivities in air are shifted to lower frequencies; the effective upper hearing limit is approximately 36 kHz (Schusterman 1974). The best range of sound detection is from 2 to 16 kHz (Schusterman, 1974). Kastak and Schusterman (2002) determined that hearing sensitivity generally worsens with depth—hearing thresholds were lower in shallow water, except at the highest frequency tested (35 kHz), where this trend was reversed. Octave band noise levels of 65 to 70 dB above the animal's threshold produced an average TTS of 4.9 dB in the California sea lion (Kastak et al. 1999). Center frequencies were 1,000 Hz for corresponding threshold testing at 1000Hz and 2,000 Hz for threshold testing at 2,000 Hz; the duration of exposure was 20 min.

4.3.3.2 Pacific Harbor Seal (*Phoca vitulina richardii*)

Stock – California, Washington/Oregon Coastal, Washington Inland

Population Status— Census data suggest an increasing population trend in California and stable populations in Washington and Oregon. The three harbor seal stocks that are recognized along the west coast of the continental United States, with estimated population numbers, are as follows (Carretta et al. 2007):

- Inland waters of Washington (including Hood Canal, Puget Sound, and the Strait of Juan de Fuca out to Cape Flattery), with an estimate of 14,612 (CV = 0.15) individuals.

- Outer coast of Oregon and Washington, with a stock estimate of 24,732 (CV = 0.12) individuals.

- California, with a stock estimate of 34,233 individuals.

Distribution—Harbor seals are considered abundant throughout most of their range from Baja California to the eastern Aleutian Islands. Harbor seals regularly occur in the OPAREA and NWTRC year-round. There are about 50 haulout sites along the coasts of Oregon and Washington, particularly in coastal estuaries an++++d along the Olympic Peninsula (Bonnell et al. 1992; Jeffries et al. 2003). Main haulout sites in Washington inland waters include the Strait of Juan de Fuca, San Juan Islands, Eastern Bays, Puget Sound, and Hood Canal (DoN 2001b; Jeffries et al. 2003). Woodard Bay and Gertrude Island are the two most important rookery sites in the Puget Sound (Calambokidis and Jeffries 1991). In Washington and Oregon, harbor seals tend to use some estuaries and bays for breeding and others primarily for feeding (Boveng 1988). Harbor seals can haul out on recreational floats, log rafts and booms, oyster rafts, fish net pens, marina floats, and breakwaters in the Puget Sound (Calambokidis and Jeffries 1991). They also haul out on submarines at SUBASE Bangor (DoN 2001b).

Aerial surveys off Oregon and Washington recorded most harbor seals within 20 km of shore in areas where water depths are less than 200 m (Bonnell et al. 1992; Calambokidis et al. 2004b). Sightings farther offshore and in deeper waters also occur (Wahl 1977; Bonnell et al. 1992). Peak abundance occurs during the pupping season and the annual molt (Jeffries et al. 2000).

Life history- Harbor seals are opportunistic feeders that adjust their patterns to take advantage of locally and seasonally abundant prey (Payne and Selzer 1989; Baird 2001; Bjørge 2002). Diet consists of fish and invertebrates (Bigg 1981; Roffe and Mate 1984; Orr et al. 2004). Although harbor seals in the Pacific Northwest are common in inshore and estuarine waters, they primarily feed at sea (Orr et al. 2004) during high tide.

Peak numbers of harbor seals haul out on land during late May to early June, which coincides with the peak of their molt. They generally favor sandy, cobble, and gravel beaches (Stewart and Yochem 1994), and most haul out on the mainland (Carretta et al. 2007). When at sea during May and June (and March to May for breeding females), they generally remain in the vicinity of haul-out sites and forage close to shore in relatively shallow waters. In coastal and inland regions of Washington, pups are born from April through January. Pups are generally born earlier in the coastal areas and later in the Puget Sound/Hood Canal region (Calambokidis and Jeffries 1991; Jeffries et al. 2000). Suckling harbor seal pups spend as much as 40% of their time in the water (Bowen et al. 1999).

Diving Behavior - While feeding, harbor seals dive to depths of 33–130 ft (10–40 m) in the case of females with nursing pups, and 260–390 ft (79–119 m) in the case of other seals. Dives as deep as 1,463 ft (446 m) have been recorded, although dives greater than 460 ft (140 m) are infrequent.

Acoustics—Harbor seals produce a variety of airborne vocalizations including snorts, snarls, and belching sounds (Bigg 1981). Adult males produce low frequency vocalizations underwater during the breeding season (Hanggi and Schusterman 1994; Van Parijs et al. 2003). Male harbor seals produce communication sounds in the frequency range of 100 to 1,000 Hz (Richardson et al. 1995).

The harbor seal hears almost equally well in air and underwater (Kastak and Schusterman 1998). Harbor seals hear best at frequencies from 1 to 180 kHz; the peak hearing sensitivity is at 32 kHz in water and 12 kHz in air (Terhune and Turnball 1995; Kastak and Schusterman 1998; Wolski et al. 2003). Kastak and Schusterman (1996) observed a TTS of 8 dB at 100 Hz from 6-7 hours of intermitten broadband continuous construction noise (sandblasting; 200-2000 Hz at 95-105 dB SPL unweighted in the seal's enclosure) per day for six days, with complete recovery approximately one week following exposure. Kastak et al. (1999) determined that underwater noise of moderate intensity (65 to 75 dB above the animals hearing threshold at 100, 500 and 1000 Hz) and continuous duration of 20 min is sufficient to induce a small TTS of 4.8 dB in harbor seals.

4.3.3.3 Northern Elephant Seal (*Mirounga angustirostris*)

Stock – California Breeding

Population Status—The California Breeding stock has recovered from near extinction in the early 1900s to an estimated 124,000 (Carretta et al. 2007).

Distribution— The northern elephant seal occurs almost exclusively in the eastern and central North Pacific. Rookeries are located from central Baja California, Mexico, to northern California (Stewart and Huber 1993). In California, they include the Channel Islands, Piedras Blancas, Cape San Martin, Año Nuevo Island and Peninsula, the Farallon Islands, and Point Reyes (Stewart et al. 1994; Carretta et al. 2006). Large rookeries, such as those on Año Nuevo Island and Peninsula and the Channel Islands, may contain thousands of seals. Elephant seals may be expanding their pupping range northward, possibly in response to the continued population growth (Hodder et al. 1998). Bonnell et al. (1992) and Hodder et al. (1998) noted a possible incipient breeding colony at Shell Island off Cape Arago in southern Oregon.

The foraging range extends thousands of kilometers offshore into the central North Pacific. Adults tend to stay offshore, but juveniles and subadults are often seen along the coasts of Oregon, Washington, and British Columbia (Condit and Le Boeuf 1984; Stewart and Huber 1993). During foraging, females may cover more than 18,000 km and males can travel more than 21,000 km (Stewart and DeLong 1995).

Northern elephant seals occur in the OPAREA year-round during their two annual migrations (Stewart and DeLong 1994). They occasionally haul out along the coasts of northern California, Oregon, Washington, and British Columbia, and regularly haul out on Shell Island off Cape Arago in southern Oregon. This island may be an incipient breeding colony (Hodder et al. 1998). Pups have been sighted there and at Protection and Minor Islands in the Puget Sound (Hodder et al. 1998; Jeffries et al. 2000).

The warm season density estimate for northern elephant seals is 0.0022 and for the cold season the density estimate is 0.0048 sea lions per square kilometer (DoN 2007a, Appendix B).

Life History-Northern elephant seals haul out on land to give birth and breed from December through March, and pups remain hauled out through April. After spending time at sea to feed (post-breeding migration), they generally return to the same areas to molt (Odell 1974; Stewart and Yochem 1984; Stewart 1989; Stewart and DeLong 1995). However, they do not necessarily return to the same beach. Adult males tend to haul out to molt between June and August (peaking in July), whereas females and juveniles haul out to most between March and May (peaking in April). Different age classes of northern elephant seals are found in the NWTRC throughout the

year (Carretta et al. 2000). For much of the year, northern elephant seals feed mostly in deep, offshore waters, and their foraging range extends thousands of kilometers offshore from the breeding range into the eastern and central North Pacific (Stewart and DeLong 1995; Stewart 1997; Le Boeuf et al. 2000). Adult males and females segregate while foraging and migrating; females mostly range west to about 173°W, between the latitudes of 40°N and 45°N, whereas males range further north into the Gulf of Alaska and along the Aleutian Islands, to between 47°N and 58°N (Stewart and Huber 1993; Stewart and DeLong 1995; Le Boeuf et al. 2000).

Diving Behavior—Both sexes routinely dive deep (up to 4,500 ft [1,370 m]) (Le Boeuf et al. 2000); dives average 15–25 min, depending on time of year, and surface intervals between dives are 2–3 min. The deepest dives recorded for both sexes are over 5,000 ft (1,524) (e.g., Le Boeuf et al. 2000; Schreer et al. 2001). Females remain submerged about 86–92 percent of the time and males about 88–90 percent (Le Boeuf et al. 1989; Stewart and Delong 1995).

Feeding juvenile northern elephant seals dive for slightly shorter periods (13–18 min), but they dive to similar depths (978 to 1,500 ft [300 to 457 m]) and spend a similar proportion (86–92 percent) of their time submerged (Le Boeuf et al. 2000).

Acoustics—The northern elephant seal produces loud, low-frequency in-air vocalizations (Bartholomew and Collias 1962). The mean fundamental frequencies are in the range of 147 to 334 Hz for adult males (Le Boeuf and Petrinovich 1974). The mean source level of the male-produced vocalizations during the breeding season is 110 dB re 20 µPa (Sanvito and Galimberti 2003). In-air calls made by aggressive males include: (1) snoring, which is a low intensity threat; (2) a snort (0.2 to 0.6 kHz) made by a dominant male when approached by a subdominant male; and (3) a clap threat (<2.5 kHz) which may contain signature information at the individual level (Richardson et al. 1995). These sounds appear to be important social cues (Shipley et al. 1992). The mean fundamental frequency of airborne calls for adult females is 500 to 1,000 Hz (Bartholomew and Collias 1962). In-air sounds produced by females include a <0.7 kHz belch roar used in aggressive situations and a 0.5 to 1 kHz bark used to attract the pup (Bartholomew and Collias 1962). As noted by Kastak and Schusterman (1999), evidence for underwater sound production by this species is scant. Except for one unsubstantiated report, none have been definitively identified (Fletcher et al. 1996; Burgess et al. 1998). Burgess et al. (1998) detected possible vocalizations in the form of click trains that resembled those used by males for communication in air.

The audiogram of the northern elephant seal indicates that this species is well-adapted for underwater hearing; sensitivity is best between 3.2 and 45 kHz, with greatest sensitivity at 6.4 kHz and an upper frequency cutoff of approximately 55 kHz (Kastak and Schusterman 1999).

4.3.3.4 Northern Fur Seal (*Callorhinus ursinus*)

Stock – Eastern Pacific, San Miguel

Listing Status- Two separate stocks of northern fur seals are recognized within U.S. waters, the Eastern Pacific Stock and the San Miguel Island Stock (Barlow et al. 1998). The Eastern Pacific Stock of northern fur seal is classified as a strategic stock because it is designated as depleted under the MMPA. The San Miguel Island Stock, which occurs north of the NWTRC, is not considered depleted or strategic under the MMPA.

Population Status—The range of the northern fur seal extends from southern California north to the Bering Sea, and west to the Okhotsk Sea and the Sea of Japan (Antonelis and Fiscus 1980).

The most recent population estimate for the Eastern Pacific Stock is 721,935 (Angliss and Outlaw 2007). Northern fur seals were made locally extinct at San Miguel Island during the mid-1800s by commercial sealing operations. After an absence of over 100 years, they recolonized the island during the late 1950s or early 1960s (DeLong 1982). The population at San Miguel Island has been increasing steadily since 1972, except for a drop in numbers during the El Niño events of 1982 (Barlow et al. 1998) and 1997–1998 (Barlow et al. 1999). The 1997 live pup count was the highest since the colony was reported in 1968, but up to 75% of those pups died within 5 months of birth. A 1998 pup count resulted in a total count of 627 pups, a 79.6% decrease from the 1997 count of 3,068 (Melin and DeLong 2000). In 1999, the population began to recover, and by 2002 the total pup count was 1,946 (Carretta et al. 2007).

The population estimate for the San Miguel Island Stock is 4,190 (Carretta et al. 2007).

Distribution—The Eastern Pacific Stock spends May–November in northern waters and at northern breeding colonies. In late November, females and young begin to arrive in offshore waters of California, with some animals moving south into continental shelf and slope waters. Maximum numbers are found in waters from 34ºN to 42ºN during February–April; most are found offshore of the continental slope. By early June, most seals of the eastern Pacific Stock have migrated back to northern waters (Antonelis and Fiscus 1980). Adult males from the Eastern Pacific Stock generally migrate only as far south as the Gulf of Alaska (Kajimura 1984).

Northern fur seals are present in the OPAREA year-round (Bonnell et al. 1992), but are most abundant between January and May. Sightings are more common off the northern Washington and Vancouver Island coasts in winter, and off central and southern Oregon in spring (Bonnell et al. 1992; Laake, J., NMFS-NMML, pers. comm., 3-6 October 2005). Migrating northern fur seals are commonly found in deep waters (>2,000 m) offshore of Oregon and Washington (Bonnell et al. 1992), and they rarely haul out on land during migrations (Bonnell et al. 1983). Some individuals, mostly juveniles, make their way into the Strait of Juan de Fuca and Puget Sound each year (Everitt et al. 1979). The warm season density estimatefor northern fur seals is 0.0 and for the coldseason the density is 0.40 fur seals per square kilometer (DoN 2007a, Appendix B).

Life History— Northern fur seals are solitary at sea but tend to congregate in food-rich areas where as many as 100 individuals have been sighted (Antonelis and Fiscus 1980; Kajimura 1984). Northern fur seals feed opportunistically on a variety of fish and squids species throughout their range (Kajimura 1984). They occur from southern California north to the Bering Sea and west to the Okhotsk Sea and Honshu Island, Japan (Carretta et al. 2006). Northern fur seals are gregarious during the breeding season and maintain a complex social structure on the rookeries. On San Miguel Island, pupping season is from late May through July (DeLong 1982). Pups are born between June and August on the Pribilof Islands (York 1987). Pups are weaned at around 4 months (Gentry 1998).The largest rookery is on St. Paul and St. George Islands in the Pribilof Islands Archipelago in Alaska. Smaller breeding colonies are located on the Kuril Islands, Robben Island, and the Commander Islands in Russia; Bogoslof Island in the southeastern Bering Sea; and San Miguel and the Farallon Islands in California (Pyle et al. 2001; Robson 2002).

Diving-Although they feed primarily in deep offshore waters, average depths of dives of lactating females are relatively shallow (223 ft [68 m]) with an average dive duration of 2.6 min

(Reeves et al. 1992). During feeding, they mostly make shallow dives of up to 164 ft (50 m), but dives can reach depths of 820 ft (250 m) (Reeves et al. 2002).

Acoustics—Northern fur seals produce underwater clicks, and in-air bleating, barking, coughing, and roaring sounds (Schusterman 1978; Richardson et al. 1995). Males vocalize (roar) almost continuously at rookeries (Gentry 1998). In-air and underwater audiograms are available for the northern fur seal. Of all the pinniped species for which hearing information is available, the northern fur seal is the most sensitive to airborne sound (Moore and Schusterman 1987). The underwater hearing range of the northern fur seal ranges from 0.5 Hz to 40 kHz (Moore and Schusterman 1987; Babushina et al. 1991). The underwater hearing threshold is 90 to 100 dB re 1 µPa-m at 1 kHz; best underwater hearing occurs between 4 and 17 to 28 kHz (Moore and Schusterman 1987; Babushina et al. 1991). The underwater hearing sensitivity of this species is 15 to 20 dB better than in the air (Babushina et al. 1991). The maximum sensitivity in air is between 2 and 16 kHz (Moore and Schustermant 1987; Babushina et al. 1991), however, there is an anomalous hearing loss at around 4 or 5 kHz (Moore and Schusterman 1987; Babushin 1999).

5 HARASSMENT AUTHORIZATION REQUESTED

The Navy requests a Letter of Authorization (LOA) for the incidental harassment of marine mammals pursuant to Section 101 (a)(5)(A) of the Marine Mammal Protection Act (MMPA). The authorization requested is for the incidental harassment of marine mammals under the MMPA due to MMPA Level A and MMPA Level B harassment. It is understood that an LOA is applicable for up to 5 years, and is appropriate where authorization for serious injury or mortality of marine mammals is requested. The request is for exercises and training events conducted within the NWTRC. These include activities that use active mid-frequency and high frequency sonar or involve explosive sources. The request is for a 5-year period commencing October 1, 2009.

The acoustic modeling approach taken in the NWTRC environmental impact statement/overseas environmental impact statement and this LOA application attempts to conservatively quantify potential exposures to marine mammals resulting from operation of mid-frequency active (MFA) and high-frequency active (HFA) sonar and explosive sources. Results from this conservative modeling approach provide an overestimation of exposures and are presented without consideration of mitigation measures employed per Navy standard operating procedures. For example, securing or turning off an active sonar when an animal approaches closer than a specified distance reduces potential exposure since the sonar is no longer transmitting and range clearance procedures and safety requirements having long set-up times for events using explosives make it very unlikely any marine mammals will be in the vicinity undetected.

Modeling results predict that for this LOA application, one species (harbor seal, one exposure) could be exposed to sonar in excess of the onset permanent threshold shift (PTS) threshold indicative of MMPA Level A harassment without consideration of mitigation measures. Given the likely detection of animals at the short distances involved for PTS to occur it is unlikely this exposure will occur. In addition, the modeling indicates 12 exposures from explosive sources that could cause slight injury, resulting in MMPA Level A harassment but zero exposures that could cause mortality.

Therefore, it is estimated that in total, there exists the potential for 13 exposures that would be classified as MMPA Level A harassment (permanent threshold shift; tympanic membrane or slight lung injury (one from MFA/HFA sonar and 12 from explosive sources). Modeling estimates no exposures to explosive sources that could cause mortality.

To reiterate an important point, the history of Navy activities in the NWTRC and analysis in this document indicate that military readiness activities are not expected to result in any sonar–induced MMPA Level A injury or mortalities to marine mammals. Neither NMFS nor the Navy anticipates that marine mammal strandings or mortality will result from the operation of MFA or HFA sonar or explosive sources during Navy exercises within the NWTRC with implementation of mitigation measures.

Neither NMFS nor the Navy anticipates that marine mammal strandings or indirectly caused mortality will result from the use of MFA or HFA sonar or underwater explosions during Navy exercises within the NWTRC. However, during the MMPA process (which allows for adaptive management), NMFS and the Navy will determine the appropriate way to proceed in the unlikely event that a causal relationship were to be found between Navy activities and a future stranding. The numbers presented in this LOA application may be modified through the MMPA process based on the available of new data and/or emergent science.

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6   NUMBERS AND SPECIES EXPOSED

The National Marine Fisheries Service (NMFS) application requires applicants to determine the number of marine mammals that are expected to be incidentally harassed by an action and the nature of the harassment (MMPA Level A or Level B). The Proposed Action is a military readiness activity as defined in the National Defense Authorization Act for Fiscal Year 2004 (Public Law 108-136), and Section 6.1.3 below defines MMPA Level A and MMPA Level B as applicable to military readiness activities. Section 6.1.3 presents how the MMPA Level A and MMPA Level B harassment definitions were relied on to develop the quantitative acoustic analysis methodologies used to assess the potential for the proposed action to affect marine mammals.

6.1   Acoustic Effects

The following mid and high frequency active sonar sources were analyzed for the NWTRC. Details of the modeling of these acoustic sources can be found in Appendix A.

- AN/SQS-53C: Surface ship sonar - mid frequency active sonar source
- AN/SQS-56: Surface ship sonar - mid frequency active sonar source
- AN/SSQ-62: Sonobuoy sonar - mid frequency active sonar source
- MK-48: Torpedo sonar. High frequency active sonar source

6.1.1   Analytical Framework for Assessing Marine Mammal Response to Active Sonar

Marine mammals respond to various types of man-made sounds introduced in the ocean environment. Responses are typically subtle and can include shorter surfacings, shorter dives, fewer blows per surfacing, longer intervals between blows (breaths), ceasing or increasing vocalizations, shortening or lengthening vocalizations, and changing frequency or intensity of vocalizations (NRC 2005). However, it is not known how these responses relate to significant effects (e.g., long-term effects or population consequences) (NRC 2005). Assessing whether a sound may disturb or injure a marine mammal involves understanding the characteristics of the acoustic sources, the marine mammals that may be present in the vicinity of the sound, and the effects that sound may have on the physiology and behavior of those marine mammals.

In estimating the potential for marine mammals to be exposed to an acoustic source, the following actions were completed:

- Evaluated potential effects within the context of existing and current regulations, thresholds, and criteria.
- Identified all acoustic sources that will be used during active sonar activities.
- Identified the location, season, and time of the action to determine which marine mammal species are likely to be present.
- Determined the estimated number of marine mammals (i.e., density) of each species that will likely be present in the respective areas during active sonar activities.
- Applied the applicable acoustic threshold criteria to the predicted sound exposures from the proposed activity. The results of this effort are then evaluated to determine

whether the predicted sound exposures from the acoustic model might be considered harassment.

- Considered potential harassment within the context of the affected marine mammal population, stock, or species to assess potential population viability. Particular focus on recruitment and survival are provided to analyze whether the effects of the action can be considered to have negligible effects to species or stocks.

The flow chart in Figure 6-1 is a representation of the general analytical framework utilized in applying the specific thresholds discussed in this section. The framework presented in the flow chart is organized from left to right and is compartmentalized according to the phenomena that occur within each. These include the physics of sound propagation (Physics), the potential physiological processes associated with sound exposure (Physiology), the potential behavioral processes that might be affected as a function of sound exposure (Behavior), and the immediate effects these changes may have on functions the animal is engaged in at the time of exposure (Life Function – Proximate). These compartmentalized effects are extended to longer term life functions (Life Function – Ultimate) and into population and species effects. Throughout the flow chart, dotted and solid lines are used to connect related events. Solid lines designate those effects that "will" happen; dotted lines designate those that "might" happen but must be considered (including those hypothesized to occur but for which there is no direct evidence).

Some boxes contained within the flow-chart are colored according to how they relate to the definitions of harassment in the Marine Mammal Protection Act (MMPA). Red boxes correspond to events that are injurious. By prior ruling and usage, these events would be considered as Level A harassment under the MMPA. Yellow boxes correspond to events that have the potential to qualify as Level B harassment under the MMPA. Based on prior ruling, the specific instance of TTS is considered as part of Level B harassment (Level B harassment includes both TTS and non-TTS). Boxes that are shaded from red to yellow have the potential for injury (Level A harassment) and behavioral disturbance (Level B harassment).

The analytical framework outlined within the flow-chart acknowledges that physiological responses must always precede behavioral responses (i.e., there can be no behavioral response without first some physiological effect of the sound) and an organization where each functional block only occurs once and all relevant inputs/outputs flow to/from a single instance.

6.1.1.1 Physics

Starting with a sound source, the attenuation of an emitted sound due to propagation loss is determined. Uniform animal distribution is overlaid onto the calculated sound fields to assess if animals are physically present at sufficient received sound levels to be considered "exposed" to the sound. If the animal is determined to be exposed, two possible scenarios must be considered with respect to the animal's physiology – effects on the auditory system and effects on nonauditory system tissues. These are not independent pathways and both must be considered since the same sound could affect both auditory and non-auditory tissues. Note that the model does not account for any animal response; rather the animals are considered stationary, accumulating energy until the threshold is tripped.
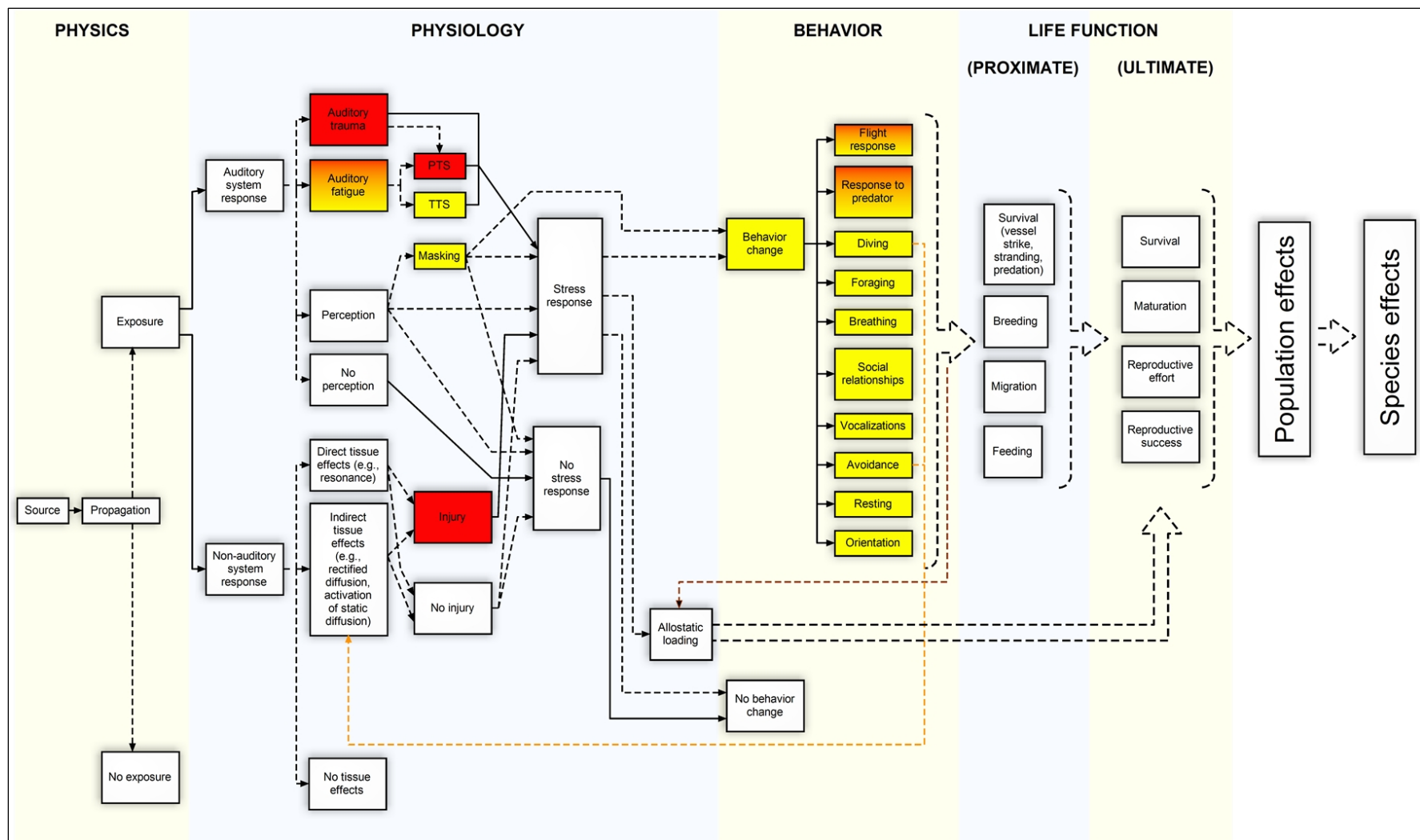
2   **Figure 6-1: Conceptual Model For Assessing The Effects Of Mid-Frequency Sonar Exposures On Marine Mammals.**

3

6.1.1.2 Physiology

Potential impacts to the auditory system are assessed by considering the characteristics of the received sound (e.g., amplitude, frequency, duration) and the sensitivity of the exposed animals. Some of these assessments can be numerically based (e.g., TTS, permanent threshold shift [PTS], perception). Others will be necessarily qualitative, due to lack of information, or will need to be extrapolated from other species for which information exists. Potential physiological responses to the sound exposure are ranked in descending order, with the most severe impact (auditory trauma) occurring at the top and the least severe impact occurring at the bottom (the sound is not perceived).

1. Auditory trauma represents direct mechanical injury to hearing related structures, including tympanic membrane rupture, disarticulation of the middle ear ossicles, and trauma to the inner ear structures such as the organ of Corti and the associated hair cells. Auditory trauma is always injurious but could be temporary and not result in PTS. Auditory trauma is always assumed to result in a stress response.

2. Auditory fatigue refers to a loss of hearing sensitivity after sound stimulation. The loss of sensitivity persists after, sometimes long after, the cessation of the sound. The mechanisms responsible for auditory fatigue differ from auditory trauma and would primarily consist of metabolic exhaustion of the hair cells and cochlear tissues. The features of the exposure (e.g., amplitude, frequency, duration, temporal pattern) and the individual animal's susceptibility would determine the severity of fatigue and whether the effects were temporary (TTS) or permanent (PTS). Auditory fatigue (PTS or TTS) is always assumed to result in a stress response.

3. Sounds with sufficient amplitude and duration to be detected among the background ambient noise are considered to be perceived. This category includes sounds from the threshold of audibility through the normal dynamic range of hearing (i.e., not capable of producing fatigue). To determine whether an animal perceives the sound, the received level, frequency, and duration of the sound are compared to what is known of the species' hearing sensitivity.

Since audible sounds may interfere with an animal's ability to detect other sounds at the same time, perceived sounds have the potential to result in auditory masking. Unlike auditory fatigue, which always results in a stress response because the sensory tissues are being stimulated beyond their normal physiological range, masking may or may not result in a stress response, depending on the degree and duration of the masking effect. Masking may also result in a unique circumstance where an animal's ability to detect other sounds is compromised without the animal's knowledge. This could conceivably result in sensory impairment and subsequent behavior change; in this case, the change in behavior is the *lack of a response* that would normally be made if sensory impairment did not occur. For this reason, masking also may lead directly to behavior change without first causing a stress response.

The features of perceived sound (e.g., amplitude, duration, temporal pattern) are also used to judge whether the sound exposure is capable of producing a stress response. Factors to consider in this decision include the probability of the animal being naïve or experienced with the sound (i.e., what are the known/unknown consequences of the exposure).

The received level is not of sufficient amplitude, frequency, and duration to be perceptible by the animal. By extension, this does not result in a stress response (not perceived).

Potential impacts to tissues other than those related to the auditory system are assessed by considering the characteristics of the sound (e.g., amplitude, frequency, duration) and the known or estimated response characteristics of nonauditory tissues. Some of these assessments can be numerically based (e.g., exposure required for rectified diffusion). Others will be necessarily qualitative, due to lack of information. Each of the potential responses may or may not result in a stress response.

1. Direct tissue effects – Direct tissue responses to sound stimulation may range from tissue shearing (injury) to mechanical vibration with no resulting injury. Any tissue injury would produce a stress response, whereas noninjurious stimulation may or may not.

2. Indirect tissue effects – Based on the amplitude, frequency, and duration of the sound, it must be assessed whether exposure is sufficient to indirectly affect tissues. For example, the hypothesis that rectified diffusion occurs is based on the idea that bubbles that naturally exist in biological tissues can be stimulated to grow by an acoustic field. Under this hypothesis, one of three things could happen: (1) bubbles grow to the extent that tissue hemorrhage occurs (injury); (2) bubbles develop to the extent that a complement immune response is triggered or nervous tissue is subjected to enough localized pressure that pain or dysfunction occurs (a stress response without injury); or (3) the bubbles are cleared by the lung without negative consequence to the animal. The probability of rectified diffusion, or any other indirect tissue effect, will necessarily be based on what is known about the specific process involved. No tissue effects – The received sound is insufficient to cause either direct mechanical) or indirect effects to tissues. No stress response occurs.

The Stress Response

The acoustic source is considered a potential stressor if, by its action on the animal, via auditory or nonauditory means, it may produce a stress response in the animal. The term "stress" has taken on an ambiguous meaning in the scientific literature, but with respect to Figure 3-1 and the later discussions of allostasis and allostatic loading, the stress response will refer to an increase in energetic expenditure that results from exposure to the stressor and which is predominantly characterized by either the stimulation of the sympathetic nervous system (SNS) or the hypothalamic-pituitary-adrenal (HPA) axis (Reeder and Kramer 2005). The SNS response to a stressor is immediate and acute and is characterized by the release of the catecholamine neurohormones norepinephrine and epinephrine (i.e., adrenaline). These hormones produce elevations in the heart and respiration rate, increase awareness, and increase the availability of glucose and lipids for energy. The HPA response is ultimately defined by increases in the secretion of the glucocorticoid steroid hormones, predominantly cortisol in mammals. The amount of increase in circulating glucocorticoids above baseline may be an indicator of the overall severity of a stress response (Hennessy et al. 1979). Each component of the stress response is variable in time; e.g., adrenalines are released nearly immediately and are used or cleared by the system quickly, whereas cortisol levels may take long periods of time to return to baseline.

The presence and magnitude of a stress response in an animal depends on a number of factors. These include the animal's life history stage (e.g., neonate, juvenile, adult), the environmental conditions, reproductive or developmental state, and experience with the stressor. Not only will these factors be subject to individual variation, but they will also vary within an individual over time. In considering potential stress responses of marine mammals to acoustic stressors, each of

these should be considered. For example, is the acoustic stressor in an area where animals engage in breeding activity? Are animals in the region resident and likely to have experience with the stressor (i.e., repeated exposures)? Is the region a foraging ground or are the animals passing through as transients? What is the ratio of young (naïve) to old (experienced) animals in the population? It is unlikely that all such questions can be answered from empirical data; however, they should be addressed in any qualitative assessment of a potential stress response as based on the available literature.

The stress response may or may not result in a behavioral change, depending on the characteristics of the exposed animal. However, provided a stress response occurs, we assume that some contribution is made to the animal's allostatic load. Allostasis is the ability of an animal to maintain stability through change by adjusting its physiology in response to both predictable and unpredictable events (McEwen and Wingfield 2003). The same hormones associated with the stress response vary naturally throughout an animal's life, providing support for particular life history events (e.g., pregnancy) and predictable environmental conditions (e.g., seasonal changes). The allostatic load is the cumulative cost of allostasis incurred by an animal and is generally characterized with respect to an animal's energetic expenditure. Perturbations to an animal that may occur with the presence of a stressor, either biological (e.g., predator) or anthropogenic (e.g., construction), can contribute to the allostatic load (Wingfield, 2003). Additional costs are cumulative and additions to the allostatic load over time may contribute to reductions in the probability of achieving ultimate life history functions (e.g., survival, maturation, reproductive effort and success) by producing pathophysiological states. The contribution to the allostatic load from a stressor requires estimating the magnitude and duration of the stress response, as well as any secondary contributions that might result from a change in behavior.

If the acoustic source does not produce tissue effects, is not perceived by the animal, or does not produce a stress response by any other means, Figure 6-1 assumes that the exposure does not contribute to the allostatic load. Additionally, without a stress response or auditory masking, it is assumed that there can be no behavioral change. Conversely, any immediate effect of exposure that produces an injury (i.e., red boxes on the flow chart in Figure 6-1) is assumed to also produce a stress response and contribute to the allostatic load.

6.1.1.3 Behavior

Acute stress responses may or may not cause a behavioral reaction. However, all changes in behavior are expected to result from an acute stress response. This expectation is based on the idea that some sort of physiological trigger must exist to change any behavior that is already being performed. The exception to this rule is the case of masking. The presence of a masking sound may not produce a stress response, but may interfere with the animal's ability to detect and discriminate biologically relevant signals. The inability to detect and discriminate biologically relevant signals hinders the potential for normal behavioral responses to auditory cues and is thus considered a behavioral change.

Numerous behavioral changes can occur as a result of stress response, and Figure 6-1 lists only those that might be considered the most common types of response for a marine animal. For each potential behavioral change, the magnitude in the change and the severity of the response needs to be estimated. Certain conditions, such as stampeding (i.e., flight response) or a response to a predator, might have a probability of resulting in injury. For example, a flight response, if

significant enough, could produce a stranding event. Under the MMPA, such an event would be considered a MMPA Level A harassment. Each altered behavior may also have the potential to disrupt biologically significant events (e.g., breeding or nursing) and may need to be qualified as MMPA Level B harassment. All behavioral disruptions have the potential to contribute to the allostatic load. This secondary potential is signified by the feedback from the collective behaviors to allostatic loading.

6.1.1.4 Life Function

Proximate Life Functions

Proximate life history functions are the functions that the animal is engaged in at the time of acoustic exposure. The disruption of these functions, and the magnitude of the disruption, is something that must be considered in determining how the ultimate life history functions are affected. Consideration of the magnitude of the effect to each of the proximate life history functions is dependent upon the life stage of the animal. For example, an animal on a breeding ground which is sexually immature will suffer relatively little consequence to disruption ofbreeding behavior when compared to an actively displaying adult of prime reproductive age.

Ultimate Life Functions

The ultimate life functions are those that enable an animal to contribute to the population (or stock, or species, etc.). The impact to ultimate life functions will depend on the nature and magnitude of the perturbation to proximate life history functions. Depending on the severity of the response to the stressor, acute perturbations may have nominal to profound impacts on ultimate life functions. For example, unit-level use of sonar by a vessel transiting through an area that is utilized for foraging, but not for breeding, may disrupt feeding by exposed animals for a brief period of time. Because of the brevity of the perturbation, the impact to ultimate life functions may be negligible. By contrast, weekly training over a period of years may have a more substantial impact because the stressor is chronic. Assessment of the magnitude of the stress response from the chronic perturbation would require an understanding of how and whether animals acclimate to a specific, repeated stressor and whether chronic elevations in the stress response (e.g., cortisol levels) produce fitness deficits.

The proximate life functions are loosely ordered in decreasing severity of impact. Mortality (survival) has an immediate effect, in that no future reproductive success is feasible and there is no further addition to the population resulting from reproduction. Severe injuries may also lead to reduced survivorship (longevity) and prolonged alterations in behavior. The latter may further affect an animal's overall reproductive success and reproductive effort. Disruptions of breeding have an immediate impact on reproductive effort and may impact reproductive success. The magnitude of the effect will depend on the duration of the disruption and the type of behavior change that was provoked. Disruptions to feeding and migration can affect all of the ultimate life functions; however, the impacts to reproductive effort and success are not likely to be as severe or immediate as those incurred by mortality and breeding disruptions.

6.1.2 Regulatory Framework

The MMPA prohibits the unauthorized harassment of marine mammals, and provides the regulatory processes for authorization for any such harassment that might occur incidental to an otherwise lawful activity.

The model for estimating potential acoustic effects from NWTRC anti-submarine warfare (ASW) training activities on cetacean species makes use of the methodology that was developed in cooperation with the National Oceanic and Atmospheric Administration (NOAA) for the Navy's Draft Overseas Environmental Impact Statement/Environmental Impact Statement, Undersea Warfare Training Range (OEIS/EIS) (DoN, 2005). Via response comment letter to Undersea Warfare Training Range (USWTR) received from NMFS dated January 30, 2006, NMFS concurred with the use of Energy Flux Density Level (EL) for the determination of physiological effects to marine mammals. Therefore, this methodology is used to estimate the annual exposure of marine mammals that may be considered MMPA Level A harassment or MMPA Level B harassment as a result of temporary, recoverable physiological effects.

In addition, the approach for estimating potential acoustic effects from training activities on marine mammal makes use of the comments received on previous Navy NEPA documents. NMFS and others who commented recommended the use of an alternate methodology to evaluate when sound exposures might result in behavioral effects without corresponding physiological effects. As a result of these comments, this analysis uses a risk function approach to evaluate the potential for MMPA Level B harassment from behavioral effects. The risk function is further explained in Section 6.2.

A number of Navy actions and NOAA rulings have helped to qualify possible events deemed as "harassment" under the MMPA. As stated previously, "harassment" under the MMPA includes both potential injury (Level A), and disruptions of natural behavioral patterns to a point where they are abandoned or significantly altered (Level B). NMFS also includes mortality as a possible outcome to consider in addition to MMPA Level A and MMPA Level B harassment. The acoustic effects analysis and exposure calculations are based on the following premises:

Harassment that may result from Navy activities described in this LOA application is unintentional and incidental to those activities.

Behavioral disruption might result in subsequent injury and injury may cause a subsequent behavioral disruption, so MMPA Level A and MMPA Level B (defined below) harassment categories can overlap and are not necessarily mutually exclusive. However, consistant with prior ruling (NOAA 2001; 2006b), this Letter of Authorization (LOA) request assumes that MMPA Level A and B do not overlap so as to preclude circular definitions of harassment.

An individual animal predicted to experience simultaneous multiple injuries, multiple disruptions, or both, is counted as a single take (see NOAA 2001; 2006b). NMFS has defined a 24-hour "refresh rate," or amount of time in which an individual can be harassed no more than once. Behavioral harassment, under the risk function presented in this request, uses received sound pressure level over a 24-hour period as the metric for determining the probability of harassment. The Navy has determined that, in a 24-hour period, all sonar activities in the NWTRC transmit for a subset of that time. Additional model assumptions account for ship movement, make adjustments for multiple ships, make adjustments for animal movement, and make adjustments for the presence of land shadows.

The acoustic effects analysis is based on primary exposures only. Secondary, or indirect, effects, such as susceptibility to predation following injury and injury resulting from disrupted behavior, while possible, can only be reliably predicted in circumstances where the responses have been well documented. Consideration of secondary effects would result in much MMPA Level A harassment being considered MMPA Level B harassment, and vice versa, since much injury

(Level A harassment) has the potential to disrupt behavior (Level B harassment), and much temporary physiological or behavioral disruption (Level B) could be conjectured to have the potential for injury (Level A). Consideration of secondary effects would lead to circular definitions of harassment.

6.1.3 Integration of Regulatory and Biological Frameworks

This section presents a biological framework within which potential effects can be categorized and then related to the existing regulatory framework of injury (MMPA Level A) and behavioral disruption (MMPA Level B). The information presented in Sections 6.4 and 6.5 is used to develop specific numerical exposure thresholds and risk function exposure estimations. Exposure thresholds are combined with sound propagation models and species distribution data to estimate the potential exposures.

6.1.3.1 Physiological and Behavioral Effects

Sound exposure may affect multiple biological traits of a marine animal; however, the MMPA as amended directs which traits should be used when determining effects. Effects that address injury are considered Level A harassment under MMPA. Effects that address behavioral disruption are considered Level B harassment under MMPA.

The biological framework proposed here is structured according to potential physiological and behavioral effects resulting from sound exposure. The range of effects may then be assessed to determine which qualify as injury or behavioral disturbance under MMPA regulations Physiology and behavior are chosen over other biological traits because:

- They are consistent with regulatory statements defining harassment by injury and harassment by disturbance.

- They are components of other biological traits that may be relevant.

- They are a more sensitive and immediate indicator of effect.

For example, ecology is not used as the basis of the framework because the ecology of an animal is dependent on the interaction of an animal with the environment. The animal's interaction with the environment is driven both by its physiological function and its behavior, and an ecological impact may not be observable over short periods of observation. Ecological information is considered in the analysis of the effects of individual species.

A "physiological effect" is defined here as one in which the "normal" physiological function of the animal is altered in response to sound exposure. Physiological function is any of a collection of processes ranging from biochemical reactions to mechanical interaction and operation of organs and tissues within an animal. A physiological effect may range from the most significant of impacts (i.e., mortality and serious injury) to lesser effects that would define the lower end of the physiological impact range, such as the non-injurious distortion of auditory tissues. This latter physiological effect is important to the integration of the biological and regulatory frameworks and will receive additional attention in later sections.

A "behavioral effect" is one in which the "normal" behavior or patterns of behavior of an animal are overtly disrupted in response to an acoustic exposure. Examples of behaviors of concern can be derived from the harassment definitions in the MMPA.

In this LOA application the term "normal" is used to qualify distinctions between physiological and behavioral effects. Its use follows the convention of normal daily variation in physiological and behavioral function without the influence of anthropogenic acoustic sources. As a result, this LOA application uses the following definitions:

- A **physiological effect** is a variation in an animal's respiratory, endocrine, hormonal, circulatory, neurological, or reproductive activity and processes, beyond the animal's normal range of variability, in response to human activity or to an exposure to a stimulus such as active sonar.

- A **behavioral effect** is a variation in the pattern of an animal's breathing, feeding, resting, migratory, intraspecific behavior (such as reproduction, mating, territorial, rearing, and agonistic behavior), and interspecific beyond the animal's normal pattern of variability in response to human activity or to an exposure to a stimulus such as active sonar.

The definitions of physiological effect and behavioral effect used within this document should not be confused with more global definitions applied to the field of biology or to existing Federal law. It is reasonable to expect some physiological effects to result in subsequent behavioral effects. For example, a marine mammal that suffers a severe injury may be expected to alter diving or foraging to the degree that its variation in these behaviors is outside that which is considered normal for the species. If a physiological effect is accompanied by a behavioral effect, the overall effect is characterized as a physiological effect; physiological effects take precedence over behavioral effects with regard to their ordering. This approach provides the most conservative ordering of effects with respect to severity, provides a rational approach to dealing with the overlap of the definitions, and avoids circular arguments.

The severity of physiological effects generally decreases with decreasing sound exposure and/or increasing distance from the sound source. The same generalization does not consistently hold for behavioral effects because they do not depend solely on the received sound level. Behavioral responses also depend on an animal's learned responses, innate response tendencies, motivational state, the pattern of the sound exposure, and the context in which the sound is presented. However, to provide a tractable approach to predicting acoustic effects that is relevant to the terms of behavioral disruption described in the MMPA, it is assumed here that the severities of behavioral effects also decrease with decreasing sound exposure and/or increasing distance from the sound source. Figure 6-2 shows the relationship between severity of effects, source distance, and exposure level, as defined in this LOA application.
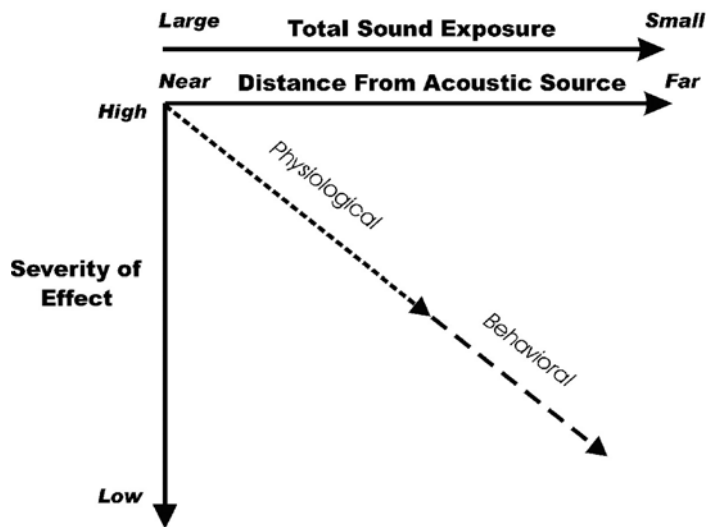
Figure 6-2: Relationship Between Severity of Effects, Source Distance, and Exposure Level.

6.1.3.2 MMPA Level A and Level B Harassment

Categorizing potential effects as either physiological or behavioral effects allows them to be related to the harassment definitions. For military readiness activities, MMPA Level A harassment includes any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild. Injury, as defined in this LOA and previous rulings (NOAA 2001; 2002a), is the destruction or loss of biological tissue. The destruction or loss of biological tissue will result in an alteration of physiological function that exceeds the normal daily physiological variation of the intact tissue. For example, increased localized histamine production, edema, production of scar tissue, activation of clotting factors, white blood cell response, etc., may be expected following injury. Therefore, this LOA assumes that all injury is qualified as a physiological effect and, to be consistent with prior actions and rulings (NOAA 2001), all injuries (slight to severe) are considered MMPA Level A harassment.

Public Law 108-136 (2004) amended the MMPA definitions of Level B harassment for military readiness activities, which applies to this action. For military readiness activities, MMPA Level B harassment is defined as "any act that disturbs or is likely to disturb a marine mammal or marine mammal stock by causing disruption of natural behavioral patterns including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering to a point where such behaviors are abandoned or significantly altered." Unlike MMPA Level A harassment, which is solely associated with physiological effects, both physiological and behavioral effects may cause MMPA Level B harassment.

For example, some physiological effects can occur that are non-injurious but that can potentially disrupt the behavior of a marine mammal. These include temporary distortions in sensory tissue that alter physiological function, but that are fully recoverable without the requirement for tissue replacement or regeneration. For example, an animal that experiences a temporary reduction in hearing sensitivity suffers no injury to its auditory system, but may not perceive some sounds due to the reduction in sensitivity. As a result, the animal may not respond to sounds that would normally produce a behavioral reaction. This lack of response qualifies as a temporary

disruption of normal behavioral patterns – the animal is impeded from responding in a normal manner to an acoustic stimulus.

The harassment status of slight behavior disruption has been addressed in workshops, previous actions, and rulings (NOAA 2001; DoN 2001a). The conclusion is that a momentary behavioral reaction of an animal to a brief, time-isolated acoustic event does not qualify as MMPA Level B harassment. A more general conclusion, that MMPA Level B harassment occurs only when there is "a potential for a significant behavioral change or response in a biologically important behavior or activity," is found in recent rulings (NOAA, 2002a). Public Law 108-136 (2004) amended the definition of MMPA Level B harassment for military readiness activities, which applies to this action. For military readiness activities, MMPA Level B harassment is defined as "any act that disturbs or is likely to disturb a marine mammal or marine mammal stock by causing disruption of natural behavioral patterns…to a point where such behaviors are abandoned or significantly altered."

Although the temporary lack of response discussed above may not result in abandonment or significant alteration of natural behavioral patterns, the acoustic effect inputs used in the acoustic model assume that temporary hearing impairment (slight to severe) is considered MMPA Level B harassment. Although modes of action are appropriately considered, as outlined in Figure 6-3, the conservative assumption used here is to consider all hearing impairment as harassment from TTS. As a result, the actual incidental harassment of marine mammals associated with this action may be less than predicted via the analytical framework.

6.1.3.3   MMPA Exposure Zones

Two acoustic modeling approaches are used to account for both physiological and behavioral effects to marine mammals. When using a threshold of accumulated energy (EL) the volumes of ocean in which MMPA Level A and MMPA Level B harassment from TTS are predicted to occur are described as exposure zones. As a conservative estimate, all marine mammals predicted to be in a zone are considered exposed to accumulated sound levels that may result in harassment within the applicable MMPA Level A (PTS) or MMPA Level B (TTS) harassment categories. MMPA Level B (risk-function) is not derived from EL, but is an estimate of the probability of behavioral responses that NMFS would classify as harassment. See Section 6.15 for a thorough description of the risk function methodology. Figure 6-3 illustrates harassment zones extending from a hypothetical, directional sound source and is for illustrative purposes only and does not represent the sizes or shapes of the actual exposure zones.

As depicted in Figure 6-3, the red MMPA Level A (PTS) exposure zone extends from the source out to the distance and exposure at which the slightest amount of injury is predicted to occur. The acoustic exposure that produces the slightest degree of injury is therefore the threshold value defining the outermost limit of the MMPA Level A exposure zone. Use of the threshold associated with the onset of slight injury as the most distant point and least injurious exposure takes account of all more serious injuries by inclusion within the MMPA Level A harassment zone.
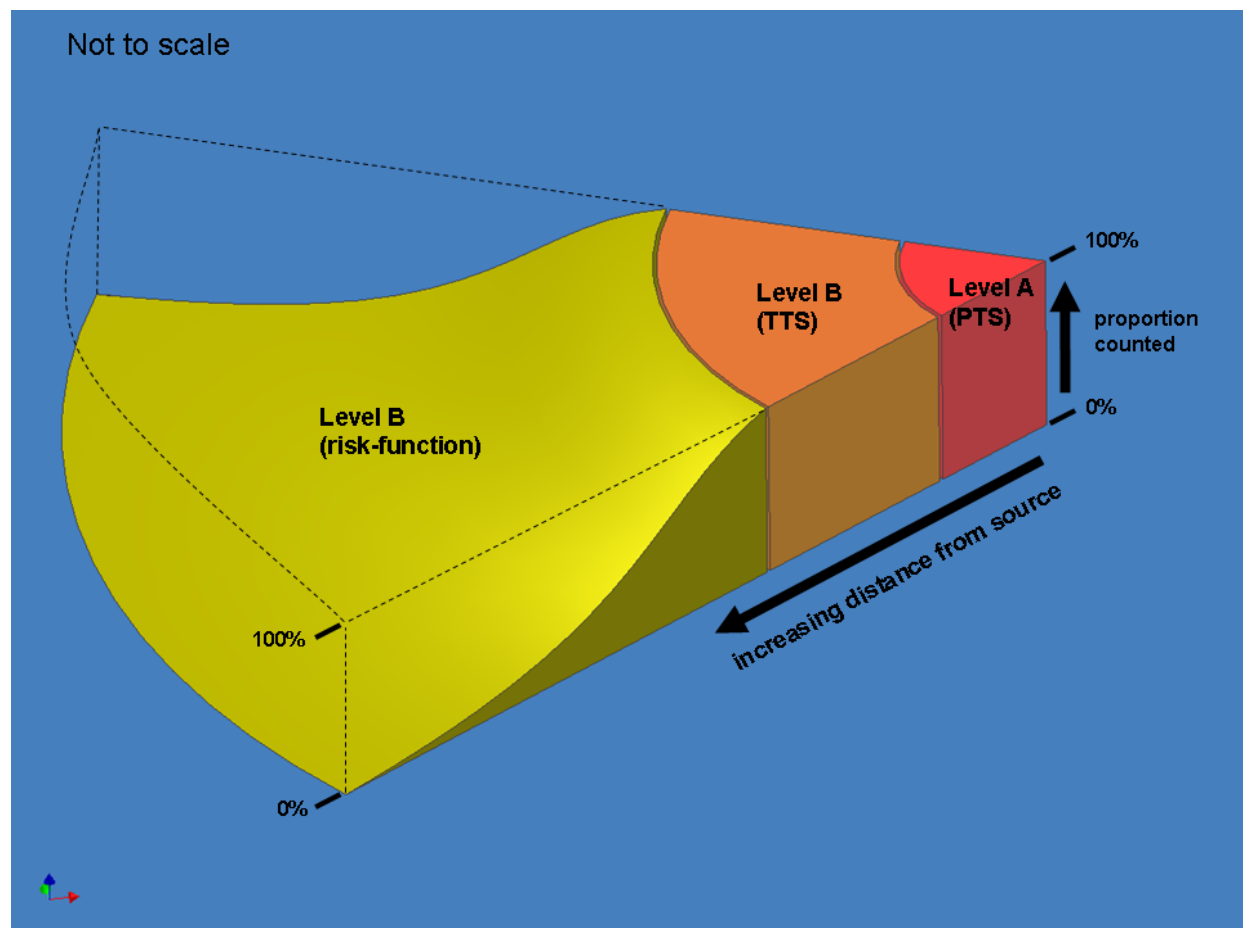
Figure 6-3: Exposure Zones Extending from a Hypothetical, Directional Sound Source.

The orange MMPA Level B (TTS) exposure zone begins just beyond the point of slightest injury and extends outward from that point to include all animals that may possibly experience MMPA Level B harassment. Physiological effects extend beyond the range of slightest injury to a point where slight temporary distortion of the most sensitive tissue occurs, but without destruction or loss of that tissue (such as occurs with inner ear hair cells subjected to temporary threshold shift). The animals predicted to be in this zone are assumed to experience MMPA Level B harassment from TTS by virtue of temporary impairment of sensory function (altered physiological function) that can disrupt behavior. The criterion and threshold used to define the outer limit of the MMPA Level B exposure zone for the on-set of certain physiological effects are given in Figure 6-3.

In the yellow MMPA Level B (risk-function) exposure zone, varying percentages of exposed animals would be included under MMPA Level B harassment.

6.1.3.4 Auditory Tissues as Indicators of Physiological Effects

Exposure to continuous-type sound may cause a variety of physiological effects in mammals. For example, exposure to very high sound levels may affect the function of the visual system, vestibular system, and internal organs (Ward 1997). Exposure to high-intensity, continuous-type sounds of sufficient duration may cause injury to the lungs and intestines (e.g., Dalecki et al.

2002). Sudden, intense sounds may elicit a "startle" response and may be followed by an orienting reflex (Ward 1997; Jansen 1998). The primary physiological effects of sound, however, are on the auditory system (Ward 1997).

The mammalian auditory system consists of the outer ear, middle ear, inner ear, and central nervous system. Sound waves are transmitted through the middle ears to fluids within the inner ear except cetaceans. The inner ear contains delicate electromechanical hair cells that convert the fluid motions into neural impulses that are sent to the brain. The hair cells within the inner ear are the most vulnerable to over-stimulation by sound exposure (Yost 1994).

Very high sound levels may rupture the eardrum or damage the small bones in the middle ear (Yost 1994). Lower level exposures of sufficient duration may cause permanent or temporary hearing loss; such an effect is called a noise-induced threshold shift, or simply a threshold shift (TS) (Miller 1974). A TS may be either permanent, in which case it is called a permanent threshold shift (PTS), or temporary, in which case it is called a temporary threshold shift (TTS). Still lower levels of sound may result in auditory masking (described in Section 3.19), which may interfere with an animal's ability to hear other concurrent sounds.

Because the tissues of the ear appear to be the most susceptible to the physiological effects of sound and TSs tend to occur at lower exposures than other more serious auditory effects, PTS and TTS are used here as the biological indicators of physiological effects. TTS is the first indication of physiological non-injurious change and is not physical injury. The remainder of this section is, therefore, focused on TSs, including PTSs and TTSs. Since masking (without a resulting TS) is not associated with abnormal physiological function, it is not considered a physiological effect in this LOA, but rather a potential behavioral effect. Descriptions of other potential physiological effects, including acoustically mediated bubble growth and air cavity resonance, are described in the Section 6.3.2.

6.1.3.5 Noise-Induced Threshold Shifts

The amount of TS depends on the amplitude, duration, frequency, and temporal pattern of the sound exposure. Threshold shifts will generally increase with the amplitude and duration of sound exposure. For continuous sounds, exposures of equal energy will lead to approximately equal effects (Ward 1997). For intermittent sounds, less TS will occur than from a continuous exposure with the same energy (some recovery will occur between exposures) (Kryter et al. 1966; Ward 1997).

The magnitude of a TS normally decreases with the amount of time post-exposure (Miller 1974). The amount of TS just after exposure is called the initial TS. If the TS eventually returns to zero (the threshold returns to the pre-exposure value), the TS is a TTS. Since the amount of TTS depends on the time post-exposure, it is common to use a subscript to indicate the time in minutes after exposure (Quaranta et al. 1998). For example, TTS2 means a TTS measured two minutes after exposure. If the TS does not return to zero but leaves some finite amount of TS, then that remaining TS is a PTS. The distinction between PTS and TTS is based on whether there is a complete recovery of a TS following a sound exposure. Figure 6-4 shows two hypothetical TSs: one that completely recovers, a TTS, and one that does not completely recover, leaving some PTS.

6.1.3.6 PTS, TTS, and Exposure Zones

PTS is non-recoverable and, by definition, must result from the destruction of tissues within the auditory system. PTS therefore qualifies as an injury and is classified as Level A harassment under the wording of the MMPA. In the NWTRC, the smallest amount of PTS (onset- PTS) is taken to be the indicator for the smallest degree of injury that can be measured. The acoustic exposure associated with onset-PTS is used to define the outer limit of the MMPA Level A exposure zone.

TTS is recoverable and, as in recent rulings (NOAA 2001; 2002a), is considered to result from the temporary, non-injurious distortion of hearing-related tissues. In the NWTRC, the smallest measurable amount of TTS (onset-TTS) is taken as the best indicator for slight temporary sensory impairment. Because it is considered non-injurious, the acoustic exposure associated with onset-TTS is used to define the outer limit of the portion of the MMPA Level B exposure zone attributable to physiological effects. This follows from the concept that hearing loss potentially affects an animal's ability to react normally to the sounds around it. Therefore, in the NWTRC, the potential for TTS is considered as a MMPA Level B harassment that is mediated by physiological effects on the auditory system.
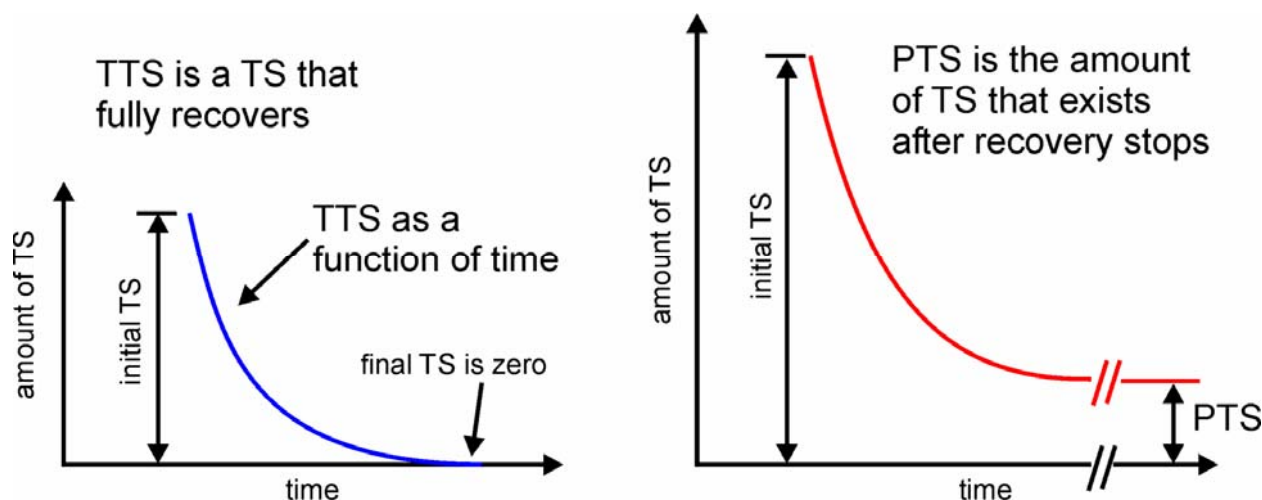
Figure 6-4: Hypothetical Temporary and Permanent Threshold Shifts

6.1.4 Criteria and Threshold for Explosive Source Effects

The criterion for mortality for marine mammals used in the CHURCHILL Final Environmental Impact Statement (FEIS) (DoN 2001) is "onset of severe lung injury." This is conservative in that it corresponds to a one percent chance of mortal injury, and yet any animal experiencing onset severe lung injury is counted as a lethal exposure.

- The threshold is stated in terms of the Goertner (1982) modified positive impulse with value "indexed to 31 psi-ms." Since the Goertner approach depends on propagation, source/animal depths, and animal mass in a complex way, the actual impulse value corresponding to the 31 pounds-per-square-inch (psi) -ms index is a complicated calculation. Again, to be conservative, CHURCHILL used the mass of a calf dolphin (at 12.2 kg), so that the threshold index is 30.5 psi-ms (Table 6.1).

The dual criteria are used for injury: onset of slight lung hemorrhage and 50 percent eardrum rupture (tympanic membrane [TM] rupture). These criteria are considered indicative of the onset of injury (Table 6-1).

- The threshold for onset of slight lung injury is calculated for a small animal (a dolphin calf weighing 27 lb), and is given in terms of the "Goertner modified positive impulse," indexed to 13 psi-ms in the (DoN 2001a). This threshold is conservative since the positive impulse needed to cause injury is proportional to animal mass, and therefore, larger animals require a higher impulse to cause the onset of injury.

- The threshold for TM rupture corresponds to a 50 percent rate of rupture (i.e., 50 percent of animals exposed to the level are expected to suffer TM rupture); this is stated in terms of an EL value of 205 dB re 1 μPa^2-s. The criterion reflects the fact that TM rupture is not necessarily a serious or life-threatening injury, but is a useful index of possible injury that is well correlated with measures of permanent hearing impairment (e.g., Ketten 1998 indicates a 30 percent incidence of PTS at the same threshold).

The dual criteria are considered for non-injurious harassment TTS, which is a temporary and recoverable loss of hearing sensitivity (NMFS 2001; DoN 2001a).

- The first criterion for TTS is 182 dB re 1 $\mu Pa2$-s maximum EL level in any 1/3-octave band at frequencies >100 hertz (Hz) for marine mammals.

- A second criterion for estimating TTS threshold has also been developed. A threshold of 12 pounds per square inch (psi) peak pressure was developed for 10,000 pound charges as part of the CHURCHILL Final EIS (DoN 2001a, [Federal Regulation (FR) 70/160, 19 Aug 05; FR 71/226, 24 Nov 06]). It was introduced to provide a more conservative safety zone for TTS when the explosive or the animal approaches the sea surface (for which case the explosive energy is reduced but the peak pressure is not). Navy policy is to use a 23 psi criterion for explosive charges less than 2,000 lb. This is below the level of onset of TTS for an odontocete (Finneran et al. 2002). All explosives modeled for the NWTRC EIS/OEIS are less than 1,500 lbs.

A third criterion is used for estimation of behavioral disturbance before TTS (sub-TTS) for cases with multiple successive explosions. The threshold is 177 dB re 1 μPa^2-s (EL) to account for behavioral effects significant enough to be judged as harassment, but occurring at lower sound energy levels than those that may cause TTS.

Table 6-1. Effects Analysis Criteria for Underwater Detonations for Explosives < 2000 lbs Net Explosive Weight

	Criterion	Metric	Threshold	Comments	Source
Mortality & Injury	Mortality Onset of extensive lung hemorrhage	Shock Wave Goertner modified positive impulse	30.5 psi-msec	All marine mammals (dolphin calf)	Goertner 1982
	Slight Injury Onset of slight lung hemorrhage	Shock Wave Goertner modified positive impulse	13.0 psi-msec	All marine mammals (dolphin calf)	Goertner 1982
	Slight Injury 50% TM Rupture	Shock Wave Energy Flux Density (EFD) for *any single exposure*	205 dB re:1μPa^2-sec	All marine mammals	DoN 2001
Harassment	Temporary Auditory Effects TTS	Noise Exposure greatest EFD in any 1/3-octave band *over all exposures*	182 dB re:1μPa^2-sec	For odontocetes greatest EFD for frequencies ≥100 Hz and for mysticetes ≥10 Hz	NMFS 2005, NMFS 2006a
	Temporary Auditory Effects TTS	Noise Exposure Peak Pressure for any single exposure	23 psi-msec	All marine mammals	NMFS 2005
	Behavioral Modification Sub-TTS	Noise Exposure greatest EFD in any 1/3-octave band *over all exposures*	177 dB re:1μPa^2-sec For multiple successive explosions	For odontocetes greatest EFD for frequencies ≥100 Hz and for mysticetes ≥10 Hz	NMFS

Notes:

Goertner, J.F. 1982. Prediction of underwater explosion safe ranges for sea mammals. Naval Surface Weapons Center, White Oak Laboratory, Silver Spring, MD. NSWC/WOL TR-82-188. 25 pp.

DoN. 2001. USS Churchill Shock Trail FEIS- February 2001. Department of the Navy.

NMFS. 2005. Notice of Issuance of an Incidental Harassment Authorization, Incidental to Conducting the Precisions Strike Weapon (PSW) Testing and Training by Eglin Air Force Base in the Gulf of Mexico. Federal Register,70(160):48675-48691.

NMFS. 2006. Incidental Takes of Marine Mammals Incidental to Specified Activities; Naval Explosive Ordnance Disposal School Training Operations at Eglin Air Force Base, Florida, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Federal Register 71(199):60693-60697

NMFS. Briefed to NMFS for VAST-IMPASS; U.S. Air Force uses 176 dB for permit applications at Eglin Gulf Test and Training Range (EGTTR)

6.1.4.1 Harassment Threshold for Multiple Successive Explosions (MSE)

There may be rare occasions when MSE are part of a static location event such as during BOMBEX, SINKEX, and GUNEX (when using other than inert weapons). For these events, the Churchill FEIS approach was extended to cover MSE events occurring at the same location. For MSE exposures, accumulated energy over the entire training time is the natural extension for energy thresholds since energy accumulates with each subsequent shot; this is consistent with the treatment of multiple arrivals in Churchill. For positive impulse, it is consistent with Churchill FEIS to use the maximum value over all impulses received.

For MSE, the acoustic criterion for sub-TTS behavioral disturbance is used to account for behavioral effects significant enough to be judged as harassment, but occurring at lower sound

energy levels than those that may cause TTS. The sub-TTS threshold is derived following the approach of the Churchill FEIS for the energy-based TTS threshold.

The research on pure-tone exposures reported in Schlundt et al. (2000) and Finneran and Schlundt (2004) provided a threshold of 192 dB re 1 μPa^2-s as the lowest TTS value. This value for pure-tone exposures is modified for explosives by (a) interpreting it as an energy metric, (b) reducing it by 10 dB to account for the time constant of the mammal ear, and (c) measuring the energy in 1/3 octave bands, the natural filter band of the ear. The resulting TTS threshold for explosives is 182 dB re 1 μPa^2-s in any 1/3 octave band. As reported by Schlundt et al. (2000) and Finneran and Schlundt (2004), instances of altered behavior in the pure-tone research generally began five dB lower than those causing TTS. The sub-TTS threshold is therefore derived by subtracting five dB from the 182 dB re 1 μPa^2-s in any 1/3 octave band threshold, resulting in a 177 dB re 1 μPa^2-s (EL) sub-TTS behavioral disturbance threshold for MSE. Table 6-2 lists the harassment thresholds for explosives.

Table 6-2. Harassment Thresholds–Explosives

Threshold Type (Explosives)	Threshold Level
Sub-TTS Threshold for Multiple Successive Explosions (peak one-third octave energy)	177 dB
MMPA Level B - Temporary Threshold Shift (TTS) (peak one-third octave energy)	182 dB
MMPA Level B - Temporary Threshold Shift (TTS) (peak pressure)	23 psi
MMPA Level A – Slight lung injury (positive impulse)	13 psi-ms
MMPA Level A – 50% Eardrum rupture	205 dB
Mortality – 1% Mortal lung injury (positive impulse)	31 psi-ms

It should be emphasized that there is a lead time for set up and clearance of any area before an event using explosives takes place (this may be 30 minutes to several hours). There will therefore be a long period of area monitoring before any detonation or live-fire event begins. Ordnance cannot be released until the target area is determined clear. Many events, such as GUNEX, may involve only inert rounds. In addition, live rounds are generally expended are immediately halted if sea turtles are observed within the target area. Training is delayed until the animal clears the target area. These mitigation factors to determine if the area is clear, serve to minimize the risk of harming sea turtles and marine mammals.

6.1.5 Criteria and Thresholds for Physiological Effects (Sensory Impairment)

This section presents the effect criteria and thresholds for physiological effects of sound leading to injury and behavioral disturbance as a result of sensory impairment. Tissues of the ear are the most susceptible to physiological effects of underwater sound. PTS and TTS were determined to be the most appropriate biological indicators of physiological effects that equate to the onset of injury (Level A harassment) and behavioral disturbance (Level B harassment from TTS), respectively. This section is, therefore, focused on criteria and thresholds to predict PTS and TTS in marine mammals.

Marine mammal ears are functionally and structurally similar to terrestrial mammal ears; however, there are important differences (Ketten 1998). The most appropriate information from which to develop PTS/TTS criteria for marine mammals would be experimental measurements

of PTS and TTS from marine mammal species of interest. TTS data exist for several marine mammal species and may be used to develop meaningful TTS criteria and thresholds. Because of the ethical issues presented, PTS data do not exist for marine mammals and are unlikely to be obtained. Therefore, PTS criteria must be extrapolated using TTS criteria and estimates of the relationship between TTS and PTS.

This section begins with a review of the existing marine mammal TTS data. The review is followed by a discussion of the relationship between TTS and PTS. The specific criteria and thresholds for TTS and PTS used in this LOA are then presented. This is followed by discussions of sound energy flux density level (EL), the relationship between EL and sound pressure level (SPL), and the use of SPL and EL in previous environmental compliance documents.

6.1.5.1 Energy Flux Density Level and Sound Pressure Level

Energy Flux Density Level (EL) is measure of the sound energy flow per unit area expressed in dB. EL is stated in dB re 1 μPa^2-s for underwater sound and dB re $(20 \mu Pa)^2$-s for airborne sound.

Sound Pressure Level (SPL) is a measure of the root-mean square, or "effective," sound pressure in decibels. SPL is expressed in dB re 1 μPa for underwater sound and dB re 20 μPa for airborne sound.

6.1.5.2 TTS in Marine Mammals

A number of investigators have measured TTS in marine mammals. These studies measured hearing thresholds in trained marine mammals before and after exposure to intense sounds. Some of the more important data obtained from these studies are onset-TTS levels – exposure levels sufficient to cause a just-measurable amount of TTS, often defined as 6 dB of TTS (for example, Schlundt et al. 2000). The existing cetacean and pinniped underwater TTS data are summarized in the following bullets.

- Schlundt et al. (2000) reported the results of TTS experiments conducted with bottlenose dolphins and white whales exposed to 1-second tones. This paper also includes a reanalysis of preliminary TTS data released in a technical report by Ridgway et al. (1997). At frequencies of 3, 10, and 20 kHz, SPLs necessary to induce measurable amounts (6 dB or more) of TTS were between 192 and 201 dB re 1 μPa (EL = 192 to 201 dB re 1 μPa^2-s). The mean exposure SPL and EL for onset-TTS were 195 dB re 1 μPa and 195 dB re 1 μPa^2-s, respectively. The sound exposure stimuli (tones) and relatively large number of test subjects (five dolphins and two white whales) make the Schlundt et al. (2000) data the most directly relevant TTS information for the scenarios described in this LOA.

- Finneran et al. (2001, 2003, 2005) described TTS experiments conducted with bottlenose dolphins exposed to 3-kHz tones with durations of 1, 2, 4, and 8 seconds. Small amounts of TTS (3 to 6 dB) were observed in one dolphin after exposure to ELs between 190 and 204 dB re 1 μPa^2-s. These results were consistent with the data of Schlundt et al. (2000) and showed that the Schlundt et al. (2000) data were not significantly affected by the masking sound used. These results also confirmed that, for tones with different durations, the amount of TTS is best correlated with the exposure EL rather than the exposure SPL.

- Finneran et al. (2007) conducted TTS experiments with bottlenose dolphins exposed to intensed 20 kHz fatiquing tone. Behavioral and auditory evoked potentials (using sinusoidal amplitude modulated tones creating auditory steady state response [AASR]) were used to measure TTS. The fatiguing tone was either 16 (mean = 193 re 1μPa, SD = 0.8) or 64 seconds (185-186 re 1μPa) in duration. TTS ranged from 19-33db from behavioral measurements and 40-45dB from ASSR measurements.

- Nachtigall et al. (2003) measured TTS in a bottlenose dolphin exposed to octave-band sound centered at 7.5 kHz. Nachtigall et al. (2003a) reported TTSs of about 11 dB measured 10 to 15 minutes after exposure to 30 to 50 minutes of sound with SPL 179 dB re 1 μPa (EL about 213 dB re μPa^2-s). No TTS was observed after exposure to the same sound at 165 and 171 dB re 1 μPa. Nachtigall et al. (2003b) reported TTSs of around 4 to 8 dB 5 minutes after exposure to 30 to 50 minutes of sound with SPL 160 dB re 1 μPa (EL about 193 to 195 dB re 1 μPa^2-s). The difference in results was attributed to faster post-exposure threshold measurement—TTS may have recovered before being detected by Nachtigall et al. (2003a). These studies showed that, for long-duration exposures, lower sound pressures are required to induce TTS than are required for short-duration tones. These data also confirmed that, for the cetaceans studied, EL is the most appropriate predictor for onset-TTS.

- Finneran et al. (2000, 2002) conducted TTS experiments with dolphins and white whales exposed to impulsive sounds similar to those produced by distant underwater explosions and seismic water guns. These studies showed that, for very short-duration impulsive sounds, higher sound pressures were required to induce TTS than for longer-duration tones.

- Kastak et al. (1999, 2005) conducted TTS experiments with three species of pinnipeds, California sea lion, northern elephant seal and a Pacific harbor seal, exposed to continuous underwater sounds at levels of 80 and 95 dB Sensation Level (referenced to the animal's absolute auditory threshold at the center frequency) at 2.5 and 3.5 kHz for up to 50 minutes. Mean TTS shifts of up to 12.2 dB occurred with the harbor seals showing the largest shift of 28.1 dB. Increasing the sound duration had a greater effect on TTS than increasing the sound level from 80 to 95 dB.

Figure 6-5 shows the existing TTS data for cetaceans (dolphins and white whales). Individual exposures are shown in terms of SPL versus exposure duration (upper panel) and EL versus exposure duration (lower panel). Exposures that produced TTS are shown as filled symbols. Exposures that did not produce TTS are represented by open symbols. The squares and triangles represent impulsive test results from Finneran et al. 2000 and 2002, respectively. The circles show the 3-, 10-, and 20-kHz data from Schlundt et al. (2000) and the results of Finneran et al. (2003). The inverted triangle represents data from Nachtigall et al. (2003b).
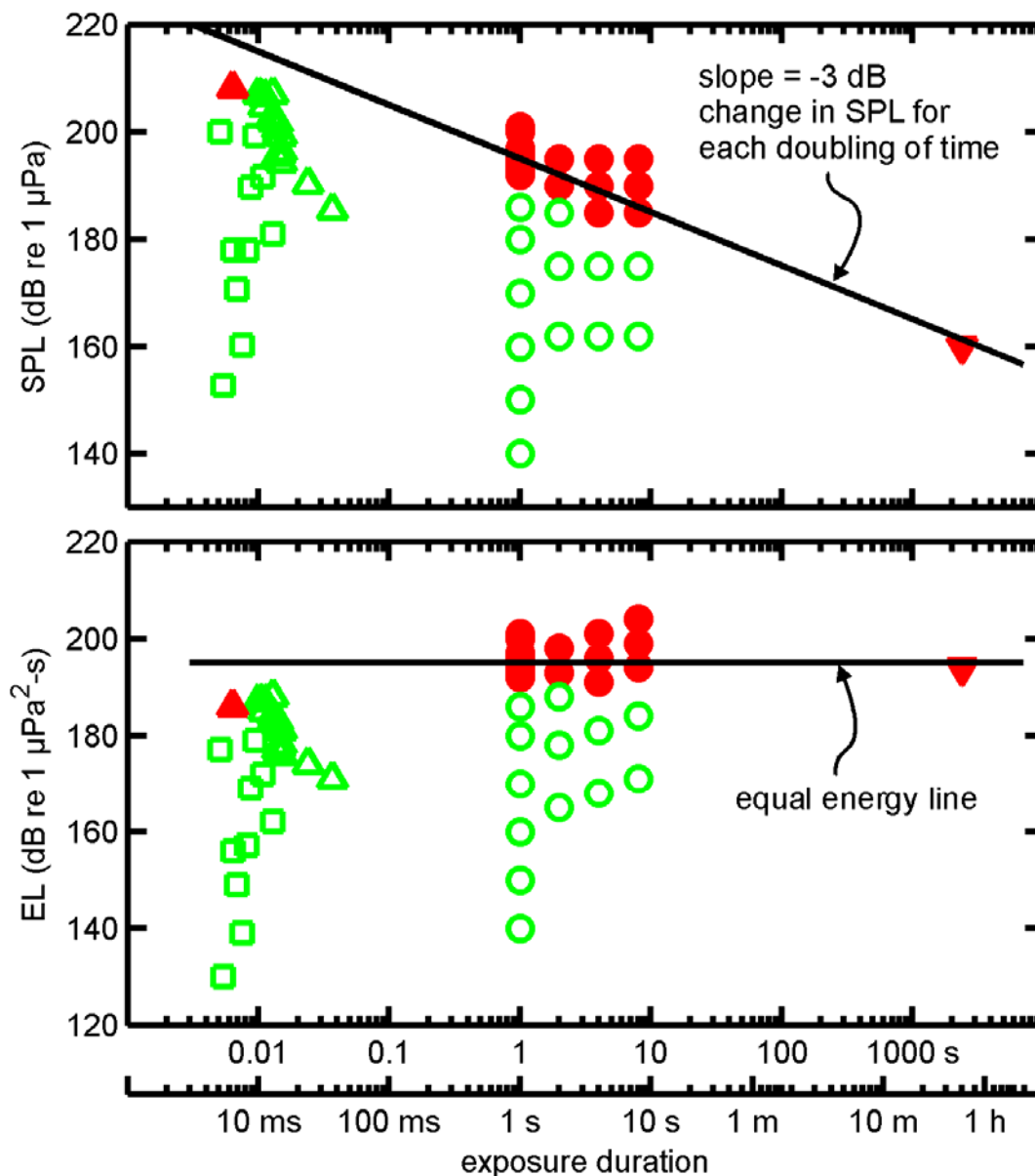
Legend: Filled symbol: Exposure that produced TTS, Open symbol: Exposure that did not produce TTS, Squares: Impulsive test results from Finneran et al. 2000, Triangles: Impulsive test results from Finneran et al. 2002, Circles: 3, 10, and 20-kHz data from Schlundt et al. (2000) and results of Finneran et al. (2003), and Inverted triangle: Data from Nachtigall et al. 2003b.

Figure 6-5: Existing TTS Data for Cetaceans.

Figure 6-5 illustrates that the effects of the different sound exposures depend on the SPL and duration. As the duration decreases, higher SPLs are required to cause TTS. In contrast, the ELs required for TTS do not show the same type of variation with exposure duration. At this time the raw data for pinnipeds is not available to construct a similar graph of TTS in pinnipeds as there is for cetaceans in Figure 6-5.

The solid line in the upper panel of Figure 6-5 has a slope of -3 dB per doubling of time. This line passes through the point where the SPL is 195 dB re 1 µPa and the exposure duration is 1

second. Since EL = SPL + 10log10 (duration), doubling the duration increases the EL by 3 dB. Subtracting 3 dB from the SPL decreases the EL by 3 dB. The line with a slope of -3 dB per doubling of time, therefore, represents an equal energy line – all points on the line have the same EL, which is, in this case, 195 dB re 1 μPa^2-s. This line appears in the lower panel as a horizontal line at 195 dB re 1 μPa^2-s. The equal energy line at 195 dB re 1 μPa^2-s fits the tonal and sound data (the non-impulsive data) very well, despite differences in exposure duration, SPL, experimental methods, and subjects.

In summary, the existing cetacean TTS data show that, for the species studied and sounds (non-impulsive) of interest, the following is true:

- The growth and recovery of TTS are analogous to those in land mammals. This means that, as in land mammals, cetacean TSs depend on the amplitude, duration, frequency content, and temporal pattern of the sound exposure. Threshold shifts will generally increase with the amplitude and duration of sound exposure. For continuous sounds, exposures of equal energy will lead to approximately equal effects (Ward 1997). For intermittent sounds, less TS will occur than from a continuous exposure with the same energy (some recovery will occur between exposures) (Kryter et al. 1965; Ward 1997).

- SPL by itself is not a good predictor of onset-TTS, since the amount of TTS depends on both SPL and duration.

- Exposure EL is correlated with the amount of TTS and is a good predictor for onset-TTS for single, continuous exposures with different durations. This agrees with human TTS data presented by Ward et al. (1958, 1959).

- An energy flux density level of 195 dB re 1 $\mu Pa2$-s is the most appropriate predictor for onset-TTS from a single, continuous exposure.

- For the purposes of this LOA application a measurable amount of 6 dB is considered the onset of TTS.

6.1.5.3 Relationship between TTS and PTS

Since marine mammal PTS data do not exist, onset-PTS levels for these animals must be estimated using TTS data and relationships between TTS and PTS. Much of the early human TTS work was directed towards relating TTS2 after 8 hours of sound exposure to the amount of PTS that would exist after years of similar daily exposures (e.g., Kryter et al. 1966). Although it is now acknowledged that susceptibility to PTS cannot be reliably predicted from TTS measurements, TTS data do provide insight into the amount of TS that may be induced without a PTS. Experimental studies of the growth of TTS may also be used to relate changes in exposure level to changes in the amount of TTS induced. Onset-PTS exposure levels may therefore be predicted by:

- Estimating the largest amount of TTS that may be induced without PTS. Exposures causing a TS greater than this value are assumed to cause PTS.

- Estimating the additional exposure, above the onset-TTS exposure, necessary to reach the maximum allowable amount of TTS that, again, may be induced without PTS. This is equivalent to estimating the growth rate of TTS – how much additional TTS is produced by an increase in exposure level.

Experimentally induced TTSs, from short duration sounds 1-8 seconds in the range of 3.5-20 kHz, in marine mammals have generally been limited to around 2 to 10 dB, well below TSs that result in some PTS. Experiments with terrestrial mammals have used much larger TSs and provide more guidance on how high a TS may rise before some PTS results. Early human TTS studies reported complete recovery of TTSs as high as 50 dB after exposure to broadband sound (Ward, 1960; Ward et al. 1958, 1959). Ward et al. (1959) also reported slower recovery times when TTS2 approached and exceeded 50 dB, suggesting that 50 dB of TTS2 may represent a "critical" TTS. Miller et al. (1963) found PTS in cats after exposures that were only slightly longer in duration than those causing 40 dB of TTS. Kryter et al. (1966) stated: "A TTS2 that approaches or exceeds 40 dB can be taken as a signal that danger to hearing is imminent." These data indicate that TSs up to 40 to 50 dB may be induced without PTS, and that 40 dB is a reasonable upper limit for TS to prevent PTS.

The small amounts of TTS produced in marine mammal studies also limit the applicability of these data to estimates of the growth rate of TTS. Fortunately, data do exist for the growth of TTS in terrestrial mammals. For moderate exposure durations (a few minutes to hours), TTS2 varies with the logarithm of exposure time (Ward et al. 1958, 1959; Quaranta et al. 1998). For shorter exposure durations the growth of TTS with exposure time appears to be less rapid (Miller 1974; Keeler 1976). For very long-duration exposures, increasing the exposure time may fail to produce any additional TTS, a condition known as asymptotic threshold shift (Saunders et al. 1977; Mills et al. 1979).

Ward et al. (1958, 1959) provided detailed information on the growth of TTS in humans. Ward et al. presented the amount of TTS measured after exposure to specific SPLs and durations of broadband sound. Since the relationship between EL, SPL, and duration is known, these same data could be presented in terms of the amount of TTS produced by exposures with different ELs.

Figure 6-6 shows results from Ward et al. (1958, 1959) plotted as the amount of TTS_2 versus the exposure EL. The data in Figure 6-6(a) are from broadband (75 Hz to 10 kHz) sound exposures with durations of 12 to 102 minutes (Ward et al. 1958). The symbols
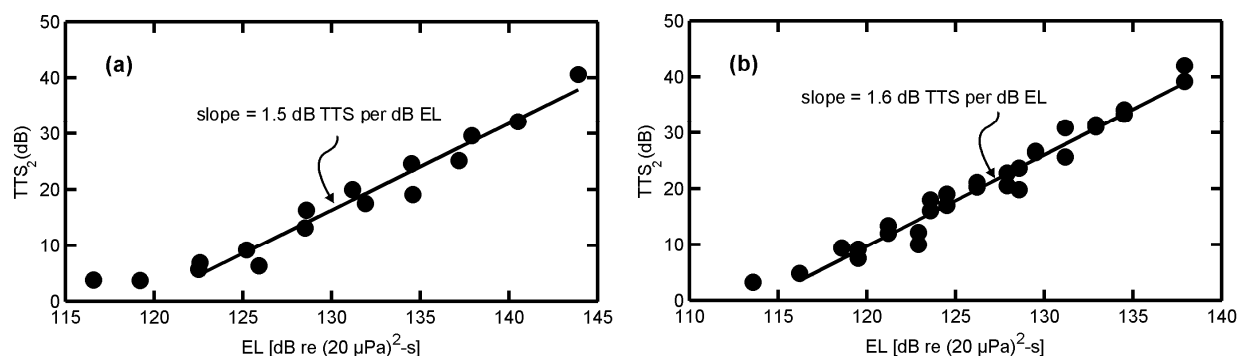
Figure 6-6: Growth of TTS versus the Exposure EL (from Ward et al. [1958, 1959])

represent mean TTS2 for 13 individuals exposed to continuous sound. The solid line is a linear regression fit to all but the two data points at the lowest exposure EL. The experimental data are fit well by the regression line (R2 = 0.95). These data are important for two reasons: (1) they confirm that the amount of TTS is correlated with the exposure EL; and (2) the slope of the line

allows one to estimate the in additional amount of TTS produced by an increase in exposure. For example, the slope of the line in Figure 6-6(a) is approximately 1.5 dB TTS_2 per dB of EL. This means that each additional dB of EL produces 1.5 dB of additional TTS_2.

The data in Figure 6-6(b) are from octave-band sound exposures (2.4 to 4.8 kHz) with durations of 12 to 102 minutes (Ward et al. 1959). The symbols represent mean TTS for 13 individuals exposed to continuous sound. The linear regression was fit to all but the two data points at the lowest exposure EL. The results are similar to those shown in Figure 3-6(a). The slope of the regression line fit to the mean TTS data was 1.6 dB TTS2/dB EL. A similar procedure was carried out for the remaining data from Ward et al. (1959), with comparable results. Regression lines fit to the TTS versus EL data had slopes ranging from 0.76 to 1.6 dB TTS2/dB EL, depending on the frequencies of the sound exposure and hearing test.

An estimate of 1.6 dB TTS_2 per dB increase in exposure EL is the upper range of values from Ward et al. (1958, 1959) and gives the most conservative estimate – it predicts a larger amount of TTS from the same exposure compared to the lines with smaller slopes. The difference between onset-TTS (6 dB) and the upper limit of TTS before PTS (40 dB) is 34 dB. To move from onset-TTS to onset-PTS, therefore, requires an increase in EL of 34 dB divided by 1.6 dB/dB, or approximately 21 dB. An estimate of 20 dB between exposures sufficient to cause onset-TTS and those capable of causing onset-PTS is a reasonable approximation.

To summarize:

In the absence of marine mammal PTS data, onset-PTS exposure levels may be estimated from marine mammal TTS data and PTS/TTS relationships observed in terrestrial mammals. This involves:

- Estimating the largest amount of TTS that may be induced without PTS. Exposures causing a TS greater than this value are assumed to cause PTS.

- Estimating the growth rate of TTS – how much additional TTS is produced by an increase in exposure level.

- A variety of terrestrial mammal data sources point toward 40 dB as a reasonable estimate of the largest amount of TS that may be induced without PTS. A conservative is that continuous-type exposures producing TSs of 40 dB or more always result in some amount of PTS.

- Data from Ward et al. (1958, 1959) reveal a linear relationship between TTS2 and exposure EL. A value of 1.6 dB TTS2 per dB increase in EL is a conservative estimate of how much additional TTS is produced by an increase in exposure level for continuous- type sounds.

- There is a 34 dB TS difference between onset-TTS (6 dB) and onset-PTS (40 dB). The additional exposure above onset-TTS that is required to reach PTS is therefore 34 dB divided by 1.6 dB/dB, or approximately 21 dB.

- Exposures with ELs 20 dB above those producing TTS may be assumed to produce a PTS. This number is used as a conservative simplification of the 21 dB number derived above.

6.1.5.4 Threshold Levels for Harassment from Physiological Effects

For this specified action, sound exposure thresholds for modeling TTS and PTS exposures are as presented in Table 6-3.

Cetaceans predicted to receive a sound exposure with EL of 215 dB re 1 μPa^2-s or greater are assumed to experience PTS and are counted as MMPA Level A harassment. Cetaceans predicted to receive a sound exposure with EL greater than or equal to 195 dB re 1 μPa^2-s but less than 215 dB re 1 μPa^2-s are assumed to experience TTS and are counted as MMPA Level B harassment from TTS.

The TTS and PTS thresholds for pinnipeds vary with species. A threshold of 206 dB re 1 μPa^2-s for TTS and 226 dB re 1 μPa^2-s for PTS is used for otariids (California sea lion, Steller sea lion, and Northern fur seal). Although this criteria is based on data from studies on California sea lions, all three species are morphologically related (e.g., similar body structure and anatomy), and have similar breeding and foraging behaviors. Northern elephant seals are similar to otariids and use thresholds of TTS = 204 dB re 1 μPa^2-s, PTS = 224 dB re 1 μPa^2-s. A lower threshold is used for harbor seals (TTS = 183 dB re 1 μPa^2-s, PTS = 203 dB re 1 μPa^2-s).

Table 6-3: Summary of the Physiological Effects Thresholds for TTS and PTS for Cetaceans and Pinnipeds.

Physiological Effects			
Animal	**Criteria**	**Threshold (re 1μPa^2-s)**	**MMPA Effect**
Cetacean	TTS	195	Level B Harassment
	PTS	215	Level A Harassment
Pinnipeds			
Northern Elephant Seal	TTS	204	Level B Harassment
	PTS	224	Level A Harassment
Pacific Harbor Seal	TTS	183	Level B Harassment
	PTS	203	Level A Harassment
California Sea Lion	TTS	206	Level B Harassment
	PTS	226	Level A Harassment
Steller Sea Lion	TTS	206	Level B Harassment
	PTS	226	Level A Harassment
Northern Fur Seal	TTS	206	Level B Harassment
	PTS	226	Level A Harassment

6.1.5.5 Derivation of Effect Threshold

6.1.5.5.1 Cetacean Threshold

The TTS threshold is primarily based on the cetacean TTS data from Schlundt et al. (2000). Since these tests used short-duration tones similar to sonar pings, they are the most directly relevant data. The mean exposure EL required to produce onset-TTS in these tests was 195 dB re 1 μPa^2-s. This result is corroborated by the short-duration tone data of Finneran et al. (2001, 2003, 2005) and the long-duration sound data from Nachtigall et al. (2003a, b). Together, these data demonstrate that TTS in cetaceans is correlated with the received EL and that onset-TTS exposures are fit well by an equal-energy line passing through 195 dB re 1 μPa^2-s.

The PTS threshold is based on a 20 dB increase in exposure EL over that required for onset-TTS. The 20 dB value is based on estimates from terrestrial mammal data of PTS occurring at 40 dB or more of TS, and on TS growth occurring at a rate of 1.6 dB/dB increase in exposure EL. This is conservative because: (1) 40 dB of TS is actually an upper limit for TTS used to approximate onset-PTS, and (2) the 1.6 dB/dB growth rate is the highest observed in the data from Ward et al. (1958, 1959).

6.1.5.5.2 Pinniped Threshold

The TTS threshold for pinnipeds is based on TTS data from Kastak et al. (1999; 2005). Although their data is from continuous noise rather than short duration tones, pinniped TTS can be extrapolated using equal energy curves. Continuous sound at a lower intensity level can produce TTS similar to short duration but higher intensity sounds such as sonar pings.

6.1.5.6 Use of EL for Physiological Effect Thresholds

Effect thresholds are expressed in terms of total received EL. Energy flux density is a measure of the flow of sound energy through an area. Marine and terrestrial mammal data show that, for continuous-type sounds of interest, TTS and PTS are more closely related to the energy in the sound exposure than to the exposure SPL.

The EL for each individual ping is calculated from the following equation:

$$EL = SPL + 10\log_{10}(\text{duration})$$

The EL includes both the ping SPL and duration. Longer-duration pings and/or higher-SPL pings will have a higher EL.

If an animal is exposed to multiple pings, the energy flux density in each individual ping is summed to calculate the total EL. Since mammalian TS data show less effect from intermittent exposures compared to continuous exposures with the same energy (Ward, 1997), basing the effect thresholds on the total received EL is a conservative approach for treating multiple pings; in reality, some recovery will occur between pings and lessen the effect of a particular exposure.

Therefore, estimates are conservative because recovery is not taken into account – intermittent exposures are considered comparable to continuous exposures.

The total EL depends on the SPL, duration, and number of pings received. The TTS and PTS thresholds do not imply any specific SPL, duration, or number of pings. The SPL and duration of each received ping are used to calculate the total EL and determine whether the received EL meets or exceeds the effect thresholds. For example, the TTS threshold would be reached through any of the following exposures:

- A single ping with SPL = 195 dB re 1 μPa and duration = 1 second.
- A single ping with SPL = 192 dB re 1 μPa and duration = 2 seconds.
- Two pings with SPL = 192 dB re 1 μPa and duration = 1 second.
- Two pings with SPL = 189 dB re 1 μPa and duration = 2 seconds.

6.1.5.7 Previous Use of EL for Physiological Effects

Originally for effects criteria from underwater explosions, energy measures were part of dual criteria for cetacean auditory effects in ship shock trials, which only involve impulsive-type sounds (DoN 1997, 2001a). These previous actions used 192 dB re 1 μPa^2-s as a reference point

to derive a TTS threshold in terms of EL. A second TTS threshold, based on peak pressure, was also used. If either threshold was exceeded, effect was assumed.

The 192 dB re 1 μPa^2-s reference point differs from the threshold of 195 dB re 1 μPa^2-s used in this LOA. The 192 dB re 1 μPa^2-s value was based on the minimum observed by Ridgway et al. (1997) and Schlundt et al. (2000) during TTS measurements with bottlenose dolphins exposed to 1-second tones. At the time, no impulsive test data for marine mammals were available and the 1-second tonal data were considered to be the best available. The minimum value of the observed range of 192 to 201 dB re 1 μPa^2-s was used to protect against misinterpretation of the sparse data set available. The 192 dB re 1 μPa^2-s value was reduced to 182 dB re 1 μPa^2-s to accommodate the potential effects of pressure peaks in impulsive waveforms.

The additional data now available for onset-TTS in small cetaceans confirm the original range of values and increase confidence in it (Finneran et al. 2001, 2003; Nachtigall et al. 2003a, 2003b). This request for the LOA therefore, uses the more complete data available and the mean value of the entire Schlundt et al. (2000) data set (195 dB re 1 μPa^2-s), instead of the minimum of 192 dB re 1 μPa^2-s. From the standpoint of statistical sampling and prediction theory, the mean is the most appropriate predictor—the "best unbiased estimator"—of the EL at which onset-TTS should occur; predicting the number of exposures in future actions relies (in part) on using the EL at which onset-TTS will most likely occur. When that EL is applied over many pings in each of many sonar exercises, that value will provide the most accurate prediction of the actual number of exposures by onset-TTS over all of those exercises. Use of the minimum value would overestimate the number of exposures because many animals counted would not have experienced onset-TTS. Further, there is no logical limiting minimum value of the distribution that would be obtained from continued successive testing. Continued testing and use of the minimum would produce more and more erroneous estimates.

6.1.6 Criteria and Thresholds for Behavioral Effects

This Section presents the effect criterion and threshold for behavioral effects of sound leading to behavioral disturbance without accompanying physiological effects. Since TTS is used as the biological indicator for a physiological effect leading to behavioral disturbance, the behavioral effects discussed in this section may be thought of as behavioral disturbance occurring at exposure levels below those causing TTS.

A large body of research on terrestrial animal and human response to airborne sound exists, but results from those studies are not readily extendible to the development of effect criteria and thresholds for marine mammals. For example, "annoyance" is one of several criteria used to define impact to humans from exposure to industrial sound sources. Comparable criteria cannot be developed for marine mammals because there is no acceptable method for determining whether a non-verbal animal is annoyed. Further, differences in hearing thresholds, dynamic range of the ear, and the typical exposure patterns of interest (e.g., human data tend to focus on 8-hour-long exposures) make extrapolation of human sound exposure standards inappropriate.

Behavioral observations of marine mammals exposed to anthropogenic sound sources exist, however, there are few observations and no controlled measurements of behavioral disruption of cetaceans caused by sound sources with frequencies, waveforms, durations, and repetition rates comparable to those employed by the tactical sonars to be used in the NWTRC. At the present time there is no consensus on how to account for behavioral effects on marine mammals exposed to continuous-type sounds (NRC 2003).

6.2 Assessing MMPA Level B Behavioral Harassment Using Risk Function

6.2.1 Background

Based on available evidence, marine animals are likely to exhibit any of a suite of potential behavioral responses or combinations of behavioral responses upon exposure to sonar transmissions. Potential behavioral responses include, but are not limited to: avoiding exposure or continued exposure; behavioral disturbance (including distress or disruption of social or foraging activity); habituation to the sound; becoming sensitized to the sound; or not responding to the sound.

Existing studies of behavioral effects of human-made sounds in marine environments remain inconclusive, partly because many of those studies have lacked adequate controls, applied only to certain kinds of exposures (which are often different from the exposures being analyzed in the study), and had limited ability to detect behavioral changes that may be significant to the biology of the animals that were being observed. These studies are further complicated by the wide variety of behavioral responses marine mammals exhibit and the fact that those responses can vary significantly by species, individuals, and the context of an exposure. In some circumstances, some individuals will continue normal behavioral activities in the presence of high levels of human-made noise. In other circumstances, the same individual or other individuals may avoid an acoustic source at much lower received levels (Richardson et al. 1995; Wartzok et al. 2003). These differences within and between individuals appear to result from a complex interaction of experience, motivation, and learning that are difficult to quantify and predict.

It is possible that some marine mammal behavioral reactions to anthropogenic sound may result in strandings. Several "mass stranding" events—strandings that involve two or more individuals of the same species (excluding a single cow–calf pair)—that have occurred over the past two decades have been associated with naval training activities, seismic surveys, and other anthropogenic activities that introduced sound into the marine environment. Sonar exposure has been identified as a contributing cause or factor in five specific mass stranding events: Greece in 1996; the Bahamas in March 2000; Madeira, Portugal in 2000; the Canary Islands in 2002, and Spain in 2006 (Marine Mammal Commission 2006).

In these circumstances, exposure to acoustic energy has been considered a potential indirect cause of the death of marine mammals (Cox et al. 2006). A popular hypothesis regarding a potential cause of the strandings is that tissue damage results from a "gas and fat embolic syndrome" (Fernandez et al. 2005; Jepson et al. 2003, 2005). Models of nitrogen saturation in diving marine mammals have been used to suggest that altered dive behavior might result in the accumulation of nitrogen gas such that the potential for nitrogen bubble formation is increased (Houser et al. 2001; Zimmer and Tyack 2007). If so, this mechanism might explain the findings of gas and bubble emboli in stranded beaked whales. It is also possible that stranding is a behavioral response to a sound under certain contextual conditions and that the subsequently observed physiological effects of the strandings (e.g., overheating, decomposition, or internal hemorrhaging from being on shore) were the result of the stranding and not the direct result of exposure to sonar (Cox et al. 2006).

6.2.2 Risk Function Adapted from Feller (1968)

To assess the potential effects on marine mammals associated with active sonar used during training activity the Navy and NMFS applied a risk function that estimates the probability of behavioral responses that NMFS would classify as harassment for the purposes of the MMPA given exposure to specific received levels of MFA sonar. The mathematical function is derived from a solution in Feller (1968) as defined in the SURTASS LFA Sonar Final OEIS/EIS (U.S. Department of the Navy, 2001), and relied on in the Supplemental SURTASS LFA Sonar EIS (U.S. Department of the Navy, 2007a) for the probability of MFA sonar risk for MMPA Level B behavioral harassment with input parameters modified by NMFS for MFA sonar for mysticetes, odontocetes (except harbor porpoises), and pinnipeds (National Marine Fisheries Service, 2008). The same risk function and input parameters will be applied to high frequency active (HFA) (>10 kHz) sources until applicable data becomes available for high frequency sources.

In order to represent a probability of risk, the function should have a value near zero at very low exposures, and a value near one for very high exposures. One class of functions that satisfies this criterion is cumulative probability distributions, a type of cumulative distribution function. In selecting a particular functional expression for risk, several criteria were identified:

- The function must use parameters to focus discussion on areas of uncertainty;
- The function should contain a limited number of parameters;
- The function should be capable of accurately fitting experimental data; and
- The function should be reasonably convenient for algebraic manipulations.

As described in DoN (2001), the mathematical function below is adapted from a solution in Feller (1968).

$$R = \frac{1 - \left(\dfrac{L-B}{K}\right)^{-A}}{1 - \left(\dfrac{L-B}{K}\right)^{-2A}}$$

Where: R = risk (0 – 1.0);

    L = Received Level (RL) in dB;

    B = basement RL in dB; (120 dB);

    K = the RL increment above basement in dB at which there is 50 percent risk;

    A = risk transition sharpness parameter (10 for odontocetes, 8 for mysticetes).

In order to use this function, the values of the three parameters (B, K, and A) need to be established. The values used in this LOA analysis are based on three sources of data: TTS experiments conducted at SSC and documented in Finneran, et al. (2001, 2003, and 2005; Finneran and Schlundt 2004); reconstruction of sound fields produced by the USS SHOUP associated with the behavioral responses of killer whales observed in Haro Strait and documented in Department of Commerce NMFS (2005); DoN (2004); and Fromm (2004a, 2004b); and observations of the behavioral response of North Atlantic right whales exposed to

alert stimuli containing mid-frequency components documented in Nowacek et al. (2004). The input parameters, as defined by NMFS, are based on very limited data that represent the best available science at this time.

6.2.2.1 Data Sources Used for Risk Function

There is widespread consensus that cetacean response to MFA sound signals needs to be better defined using controlled experiments. Navy is contributing to an ongoing behavioral response study in the Bahamas that is anticipated to provide some initial information on beaked whales, the species identified as the most sensitive to MFA sonar. NMFS is leading this international effort with scientists from various academic institutions and research organizations to conduct studies on how marine mammals respond to underwater sound exposures.

Until additional data is available, NMFS and the Navy have determined that the following three data sets are most applicable for the direct use in developing risk function parameters for MFA/HFA sonar. These data sets represent the only known data that specifically relate altered behavioral responses to exposure to MFA sound sources.

Data from SSC's Controlled Experiments

Most of the observations of the behavioral responses of toothed whales resulted from a series of controlled experiments on bottlenose dolphins and beluga whales conducted by researchers at SSC's facility in San Diego, California (Finneran et al. 2001, 2003, 2005; Finneran and Schlundt 2004; Schlundt et al. 2000). In experimental trials with marine mammals trained to perform tasks when prompted, scientists evaluated whether the marine mammals performed these tasks when exposed to mid-frequency tones. Altered behavior during experimental trials usually involved refusal of animals to return to the site of the sound stimulus. This refusal included what appeared to be deliberate attempts to avoid a sound exposure or to avoid the location of the exposure site during subsequent tests. (Schlundt et al. 2000, Finneran et al. 2002) Bottlenose dolphins exposed to 1-sec intense tones exhibited short-term changes in behavior above received sound levels of 178 to 193 dB re 1 micropascal (μPa) root mean square (rms), and beluga whales did so at received levels of 180 to 196 dB and above. Test animals sometimes vocalized after an exposure to impulsive sound from a seismic watergun (Finneran et al. 2002). In some instances, animals exhibited aggressive behavior toward the test apparatus (Ridgway et al. 1997; Schlundt et al. 2000).

Finneran and Schlundt (2004) examined behavioral observations recorded by the trainers or test coordinators during the Schlundt et al. (2000) and Finneran et al. (2001, 2003, 2005) experiments featuring 1-second (sec) tones. These included observations from 193 exposure sessions (fatiguing stimulus level > 141 dB re 1μPa) conducted by Schlundt et al. (2000) and 21 exposure sessions conducted by Finneran et al. (2001, 2003, 2005). The observations were made during exposures to sound sources at 0.4 kHz, 3 kHz, 10 kHz, 20 kHz, and 75 kHz. The TTS experiments that supported Finneran and Schlundt (2004) are further explained below:

Schlundt et al. (2000) provided a detailed summary of the behavioral responses of trained marine mammals during TTS tests conducted at SSC San Diego with 1-sec tones. Schlundt et al. (2000) reported eight individual TTS experiments. Fatiguing stimuli durations were 1-sec; exposure frequencies were 0.4 kHz, 3 kHz, 10 kHz, 20 kHz and 75 kHz. The experiments were conducted in San Diego Bay. Because of the variable ambient noise in the bay, low-level broadband masking noise was used to keep hearing thresholds consistent despite fluctuations in the ambient

noise. Schlundt et al. (2000) reported that "behavioral alterations," or deviations from the behaviors the animals being tested had been trained to exhibit, occurred as the animals were exposed to increasing fatiguing stimulus levels.

Finneran et al. (2001, 2003, 2005) conducted TTS experiments using tones at 3 kHz. The test method was similar to that of Schlundt et al. (2000) except the tests were conducted in a pool with very low ambient noise level (below 50 dB re 1 μPa/hertz [Hz]), and no masking noise was used. Two separate experiments were conducted using 1-sec tones. In the first, fatiguing sound levels were increased from 160 to 201 dB SPL. In the second experiment, fatiguing sound levels between 180 and 200 dB re 1 μPa were randomly presented.

Data from Studies of Baleen (Mysticetes) Whale Responses

The only mysticete data available resulted from a field experiments in which baleen whales (mysticetes) were exposed to a range frequency sound sources from 120 Hz to 4500 Hz (Nowacek et al. 2004). An alert stimulus, with a mid-frequency component, was the only portion of the study used to support the risk function input parameters.

Nowacek et al. (2004) documented observations of the behavioral response of North Atlantic right whales exposed to alert stimuli containing mid-frequency components. To assess risk factors involved in ship strikes, a multi-sensor acoustic tag was used to measure the responses of whales to passing ships and experimentally tested their responses to controlled sound exposures, which included recordings of ship noise, the social sounds of conspecifics and a signal designed to alert the whales. The alert signal was 18-minutes of exposure consisting of three 2-minute signals played sequentially three times over. The three signals had a 60 percent duty cycle and consisted of: (1) alternating 1-sec pure tones at 500 Hz and 850 Hz; (2) a 2-sec logarithmic down-sweep from 4,500 Hz to 500 Hz; and (3) a pair of low (1,500 Hz)-high (2,000 Hz) sine wave tones amplitude modulated at 120 Hz and each 1-sec long. The purposes of the alert signal were (a) to provoke an action from the whales via the auditory system with disharmonic signals that cover the whales estimated hearing range; (b) to maximize the signal to noise ratio (obtain the largest difference between background noise) and c) to provide localization cues for the whale. Five out of six whales reacted to the signal designed to elicit such behavior. Maximum received levels ranged from 133 to 148 dB re 1μPa.

Observations of Killer Whales in Haro Strait in the Wild

In May 2003, killer whales (*Orcinus orca*) were observed exhibiting behavioral responses while the USS SHOUP was engaged in MFA sonar activities in the Haro Strait in the vicinity of Puget Sound, Washington. Although these observations were made in an uncontrolled environment, the sound field that may have been associated with the sonar activities had to be estimated, and the behavioral observations were reported for groups of whales, not individual whales, the observations associated with the USS SHOUP provide the only data set available of the behavioral responses of wild, non-captive animal upon exposure to the AN/SQS-53 MFA sonar.

U.S. Department of Commerce (National Marine Fisheries, 2005); U.S. Department of the Navy (2004); Fromm (2004a, 2004b) documented reconstruction of sound fields produced by the USS SHOUP associated with the behavioral response of killer whales observed in Haro Strait. Observations from this reconstruction included an approximate closest approach time which was

correlated to a reconstructed estimate of received level at an approximate whale location (which ranged from 150 to 180 dB), with a mean value of 169.3 dB.

6.2.2.2 Limitations of the Risk Function Data Sources

There are significant limitations and challenges to any risk function derived to estimate the probability of marine mammal behavioral responses; these are largely attributable to sparse data. Ultimately there should be multiple functions for different marine mammal taxonomic groups, but the current data are insufficient to support them. The goal is unquestionably that risk functions be based on empirical measurement.

The risk function presented here is based on three data sets that NMFS and Navy have determined are the best available science at this time. The Navy and NMFS acknowledge each of these data sets has limitations. However, this risk function, if informed by the limited available data relevant to the MFA sonar application, has the advantages of simplicity and the fact that there is precedent for its application and foundation in marine mammal research.

While NMFS considers all data sets as being weighted equally in the development of the risk function, the Navy believes the SSC San Diego data is the most rigorous and applicable for the following reasons:

- The data represents the only source of information where the researchers had complete control over and ability to quantify the noise exposure conditions.

- The altered behaviors were identifiable due to long term observations of the animals.

- The fatiguing noise consisted of tonal exposures with limited frequencies contained in the MFA sonar bandwidth.

However, the Navy and NMFS do agree that the following are limitations associated with the three data sets used as the basis of the risk function:

- The three data sets represent the responses of only four species: trained bottlenose dolphins and beluga whales, North Atlantic right whales in the wild and killer whales in the wild.

- None of the three data sets represent experiments designed for behavioral observations of animals exposed to MFA sonar.

- The behavioral responses of marine mammals that were observed in the wild (observations of killer whales in Haro Strait) are based on an estimated received level of sound exposure; they do not take into consideration (due to minimal or no supporting data):

  o Potential relationships between acoustic exposures and specific behavioral activities (e.g., feeding, reproduction, changes in diving behavior, etc.), variables such as bathymetry, or acoustic waveguides; or

  o Differences in individuals, populations, or species, or the prior experiences, reproductive state, hearing sensitivity, or age of the marine mammal.

SSC San Diego Trained Bottlenose Dolphins and Beluga Data Set

- The animals were trained animals in captivity; therefore, they may be more or less sensitive than cetaceans found in the wild (Domjan, 1998).

- The tests were designed to measure TTS, not behavior.

- Because the tests were designed to measure TTS, the animals were exposed to much higher levels of sound than the baseline risk function (only two of the total 193 observations were at levels below 160 dB re 1 μPa2-s).

- The animals were not exposed in the open ocean but in a shallow bay or pool.

North Atlantic Right Whales in the Wild Data Set

- The observations of behavioral response were from exposure to alert stimuli that contained mid-frequency components but was not similar to a MFA sonar ping. The alert signal was 18 minutes of exposure consisting of three 2-minute signals played sequentially three times over. The three signals had a 60 percent duty cycle and consisted of: (1) alternating 1-sec pure tones at 500 Hz and 850 Hz; (2) a 2-sec logarithmic down-sweep from 4,500 Hz to 500 Hz; and (3) a pair of low (1,500 Hz)-high (2,000 Hz) sine wave tones amplitude modulated at 120 Hz and each 1-sec long. This 18-minute alert stimuli is in contrast to the average 1-sec ping every 30 sec in a comparatively very narrow frequency band used by military sonar.

- The purpose of the alert signal was, in part, to provoke an action from the whales through an auditory stimulus.

Killer Whales in the Wild Data Set

- The observations of behavioral harassment were complicated by the fact that there were other sources of harassment in the vicinity (other vessels and their interaction with the animals during the observation).

- The observations were anecdotal and inconsistent. There were no controls during the observation period, with no way to assess the relative magnitude of the any observed response as opposed to baseline conditions.

6.2.2.3   Input Parameters for the Risk Function

The values of B, K, and A need to be specified in order to utilize the risk function defined in Section 6.2.2. The risk continuum function approximates the dose-response function in a manner analogous to pharmacological risk assessment. In this case, the risk function is combined with the distribution of sound exposure levels to estimate aggregate impact on an exposed population.

Basement Value for Risk—The B Parameter

The B parameter defines the basement value for risk, below which the risk is so low that calculations are impractical. This 120 dB level is taken as the estimate received level (RL) below which the risk of significant change in a biologically important behavior approaches zero for the MFA/HFA sonar risk assessment. This level is based on a broad overview of the levels at which multiple species have been reported responding to a variety of sound sources, both mid-frequency and other, was recommended by the NMFS, and has been used in other publications. The Navy recognizes that for actual risk of changes in behavior to be zero, the signal-to-noise ratio of the animal must also be zero. However, the present convention of ending the risk calculation at 120 dB for MFA/HFA sonar has a negligible impact on the subsequent calculations, because the risk function does not attain appreciable values at received levels that low.

The K Parameter

NMFS and the Navy used the mean of the following values to define the midpoint of the function: (1) the mean of the lowest received levels (185.3 dB) at which individuals responded with altered behavior to 3 kHz tones in the SSC data set; (2) the estimated mean received level value of 169.3 dB produced by the reconstruction of the USS SHOUP incident in which killer whales exposed to MFA sonar (range modeled possible received levels: 150 to 180 dB); and (3) the mean of the 5 maximum received levels at which Nowacek et al. (2004) observed significantly altered responses of right whales to the alert stimuli than to the control (no input signal) is 139.2 dB SPL. The arithmetic mean of these three mean values is 165 dB SPL. The value of K is the difference between the value of B (120 dB SPL) and the 50 percent value of 165 dB SPL; therefore, K=45.

Risk Transition—The A Parameter

The A parameter controls how rapidly risk transitions from low to high values with increasing receive level. As A increases, the slope of the risk function increases. For very large values of A, the risk function can approximate a threshold response or step function. NMFS has recommended that Navy use A=10 as the value for odontocetes (except harbor porpoises), and pinnipeds, and A=8 for mysticetes (Figures 6-7 and 6-8) (NMFS 2008)
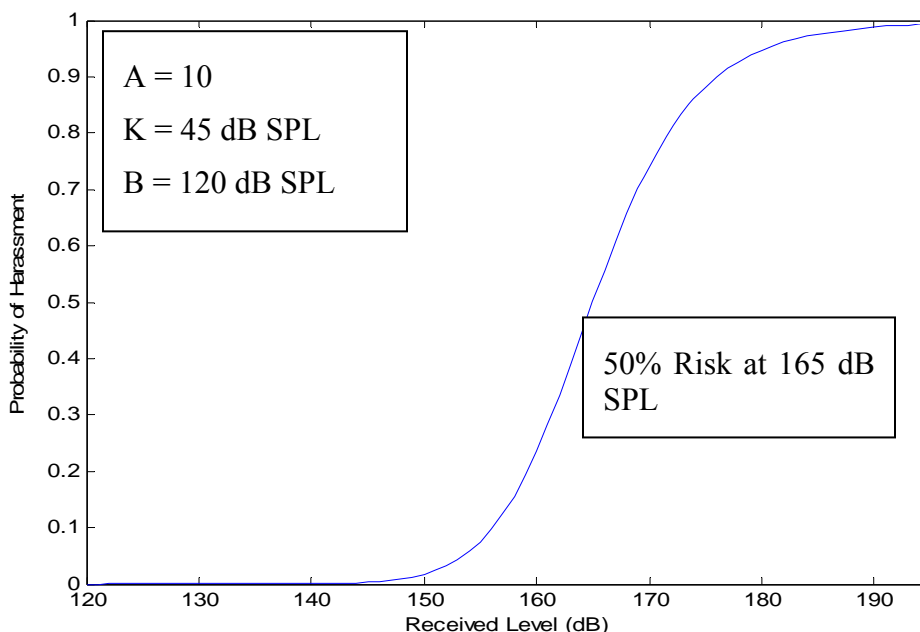
Figure 6-7: Risk Function Curve for Odontocetes (Toothed Whales) and Pinnipeds
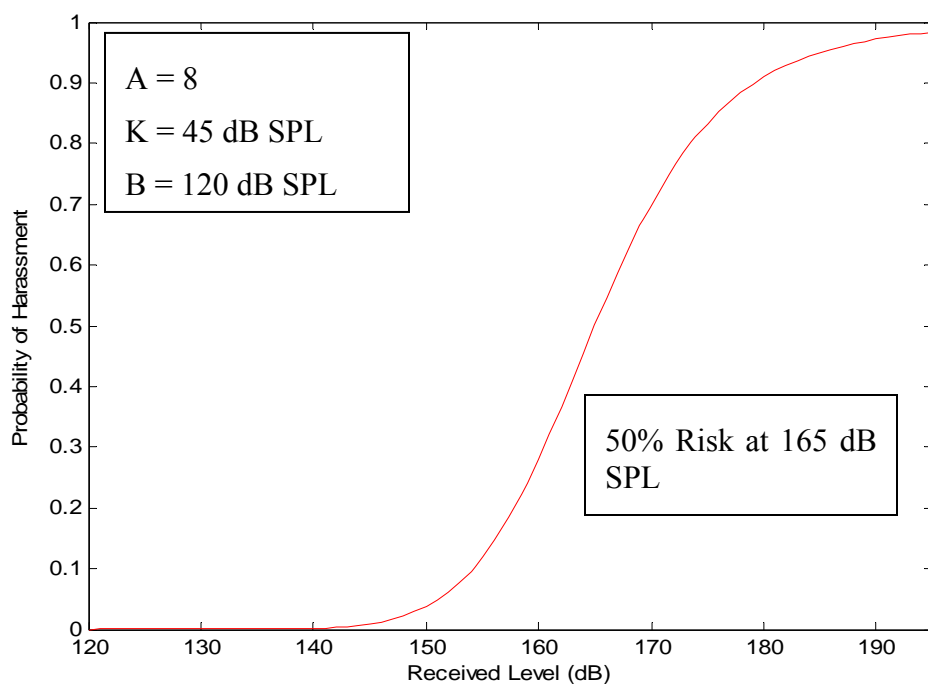
Figure 6-8: Risk Function Curve for Mysticetes (Baleen Whales)

Justification for the Steepness Parameter of A=10 for the Odontocete Curve

The NMFS independent review process described in Section 4.1.2.4.9 of DoN (2008) provided the impetus for the selection of the parameters for the risk function curves. One scientist recommended staying close to the risk continuum concept as used in the SURTASS LFA sonar EIS. This scientist opined that both the basement and slope values; B=120 dB and A=10 respectively, from the SURTASS LFA sonar risk continuum concept are logical solutions in the absence of compelling data to select alternate values supporting the Feller-adapted risk function for MFA sonar. Another scientist indicated a steepness parameter needed to be selected, but did not recommend a value. Four scientists did not specifically address selection of a slope value. After reviewing the six scientists' recommendations, the two NMFS scientists recommended selection of A=10. Direction was provided by NMFS to use the A=10 curve for odontocetes based on the scientific review of potential risk functions explained in Section 4.1.2.4.9.2 of DoN (2008).

As background, a sensitivity analysis of the A=10 parameter was undertaken and presented in Appendix D of the SURTASS/LFA FEIS (DoN 2001c). The analysis was performed to support the A=10 parameter for mysticete whales responding to a low-frequency sound source, a frequency range to which the mysticete whales are believed to be most sensitive to. The sensitivity analysis results confirmed the increased risk estimate for animals exposed to sound levels below 165 dB. Results from the Low Frequency Sound Scientific Research Program (LFS SRP) phase II research showed that whales (specifically gray whales in their case) did scale their responses with received level as supported by the A=10 parameter (Buck and Tyack 2000). In the second phase of the LFS SRP research, migrating gray whales showed responses similar to those observed in earlier research (Malme et al. 1983, 1984) when the low frequency source was

moored in the migration corridor (2 km [1.1 nm] from shore). The study extended those results with confirmation that a louder SL elicited a larger scale avoidance response. However, when the source was placed offshore (4 km [2.2 nm] from shore) of the migration corridor, the avoidance response was not evident. This implies that the inshore avoidance model – in which 50 percent of the whales avoid exposure to levels of 141 + 3 dB – may not be valid for whales in proximity to an offshore source (DoN 2001c). As concluded in the SURTASS LFA Sonar Final OEIS/EIS (DoN 2001c), the value of A=10 produces a curve that has a more gradual transition than the curves developed by the analyses of migratory gray whale studies (Malme et al. 1984; Buck and Tyack 2000; and SURTASS LFA Sonar EIS, Subchapters 1.43, 4.2.4.3 and Appendix D, and NMFS 2008).

Justification for the steepness parameter of A=8 for the Mysticete Curve

The Nowacek et al. (2004) study provides the only available data source for a mysticete species behaviorally responding to a sound source (i.e., alert stimuli) with frequencies in the range of tactical mid-frequency sonar (1-10 kHz), including empirical measurements of received levels (RLs). While there are fundamental differences in the stimulus used by Nowacek et al. (2004) and tactical mid-frequency sonar (e.g., source level, waveform, duration, directionality, likely range from source to receiver), they are generally similar in frequency band and the presence of modulation patterns. Thus, while they must be considered with caution in interpreting behavioral responses of mysticetes to mid-frequency sonar, they seemingly cannot be excluded from this consideration given the overwhelming lack of other information. The Nowacek et al. (2004) data indicate that five out the six North Atlantic right whales exposed to an alert stimuli "significantly altered their regular behavior and did so in identical fashion" (i.e., ceasing feeding and swimming to just under the surface). For these five whales, maximum RLs associated with this response ranged from root- mean-square sound (rms) pressure levels of 133-148 dB (re: 1 µPa).

When six scientists (one of them being Nowacek) were asked to independently evaluate available data for constructing a dose response curve based on a solution adapted from Feller (1968), the majority of them (4 out of 6; one being Nowacek) indicated that the Nowacek et al. (2004) data were not only appropriate but also necessary to consider in the analysis. While other parameters associated with the solution adapted from Feller (1968) were provided by many of the scientists (i.e., basement parameter [B], increment above basement where there is 50% risk [K]), only one scientist provided a suggestion for the risk transition parameter, A.

A single curve may provide the simplest quantitative solution to estimating behavioral harassment. However, the policy decision, by NMFS-OPR, to adjust the risk transition parameter from A=10 to A=8 for mysticetes and create a separate curve was based on the fact the use of this shallower slope better reflected the increased risk of behavioral response at relatively low RLs suggested by the Nowacek et al. (2004) data. In other words, by reducing the risk transition parameter from 10 to 8, the slope of the curve for mysticetes is reduced. This results in an increase the proportion of the population being classified as behaviorally harassed at lower RLs. It also slightly reduces the estimate of behavioral response probability at quite high RLs, though this is expected to have quite little practical result owing to the very limited probability of exposures well above the mid-point of the function. This adjustment allows for a slightly more conservative approach in estimating behavioral harassment at relatively low RLs for mysticetes compared to the odontocete curve and is supported by the only dataset currently available. It should be noted that the current approach (with A=8) still yields an extremely low probability for behavioral responses at RLs between 133-148 dB, where the Nowacek data indicated significant

responses in a majority of whales studied. (Note: Creating an entire curve based strictly on the Nowacek et al. [2004] data alone for mysticetes was advocated by several of the reviewers and considered inappropriate, by NMFS-OPR, since the sound source used in this study was not identical to tactical mid-frequency sonar, and there were only five data points available). The policy adjustment made by NMFS-OPR was also intended to capture some of the additional recommendations and considerations provided by the scientific panel (i.e., the curve should be more data driven and that a greater probability of risk at lower RLs be associated with direct application of the Nowacek et al. 2004 data).

6.2.2.4 Harbor Porpoises

The information currently available regarding these inshore species that inhabit shallow and coastal waters suggests a very low threshold level of response for both captive and wild animals. Threshold levels at which both captive (e.g. Kastelein et al. 2000; Kastelein et al. 2005; Kastelein et al. 2006) and wild harbor porpoises (e.g. Johnston, 2002) responded to sound (e.g. acoustic harassment devices (AHDs), acoustic deterrent devices (ADDs), or other non-pulsed sound sources) is very low (e.g. ~120 dB SPL), although the biological significance of the disturbance is uncertain. Therefore, Navy will not use the risk function curve as presented but will apply a step function threshold of 120 dB SPL to estimate take of harbor porpoises (i.e., assumes that all harbor porpoises exposed to 120 dB or higher MFAS will respond in a way NMFS considers behavioral harassment).

6.2.3 Application of the Risk Function and Current Regulatory Scheme

The risk function is used to estimate the percentage of an exposed population that is likely to exhibit behaviors that would qualify as harassment (as that term is defined by the MMPA applicable to military readiness activities, such as the Navy's training and testing with mid- and high-frequency active sonar) at a given received level of sound. For example, at 165 dB SPL (dB re: 1μPa rms), the risk (or probability) of harassment is defined according to this function as 50 percent, and Navy/NMFS applies that by estimating that 50 percent of the individuals exposed at that received level are likely to respond by exhibiting behavior that NMFS would classify as behavioral harassment. The risk function is not applied to individual animals, only to exposed populations.

The data used to produce the risk function were compiled from four species that had been exposed to sound sources in a variety of different circumstances. As a result, the risk function represents a general relationship between acoustic exposures and behavioral responses that is then applied to specific circumstances. That is, the risk function represents a relationship that is deemed to be generally true, based on the limited, best-available science, but may not be true in specific circumstances. In particular, the risk function, as currently derived, treats the received level as the only variable that is relevant to a marine mammal's behavioral response. However, we know that many other variables—the marine mammal's gender, age, and prior experience; the activity it is engaged in during an exposure event, its distance from a sound source, the number of sound sources, and whether the sound sources are approaching or moving away from the animal—can be critically important in determining whether and how a marine mammal will respond to a sound source (Southall et al. 2007). The data that are currently available do not allow for incorporation of these other variables in the current risk functions; however, the risk function represents the best use of the data that are available.

As more specific and applicable data become available, NMFS can use these data to modify the outputs generated by the risk function to make them more realistic (and ultimately, data may exist to justify the use of additional, alternate, or multi-variate functions). As mentioned above, it is known that the distance from the sound source and whether it is perceived as approaching or moviNWTRC HRC example, animals exposed to received levels between 120 and 130 dB may be more than 65 nautical miles (131,651 yards) from a sound source; those distances would influence whether those animals might perceive the sound source as a potential threat, and their behavioral responses to that threat. Though there are data showing marine mammal responses to sound sources at that received level, NMFS does not currently have any data that describe the response of marine mammals to sounds at that distance (or to other contextual aspects of the exposure, such as the presence of higher frequency harmonics), much less data that compare responses to similar sound levels at varying distances. However, if data were to become available that suggested animals were less likely to respond (in a manner NMFS would classify as harassment) to certain levels beyond certain distances, or that they were more likely to respond at certain closer distances, Navy will re-evaluate the risk function to try to incorporate any additional variables into the "take" estimates.

Last, pursuant to the MMPA, an applicant is required to estimate the number of animals that will be "taken" by their activities. This estimate informs the analysis that NMFS must perform to determine whether the activity will have a "negligible impact" on the species or stock. Level B (behavioral) harassment occurs at the level of the individual(s) and does not assume any resulting population-level consequences, though there are known avenues through which behavioral disturbance of individuals can result in population-level effects. Alternately, a negligible impact finding is based on the lack of likely adverse effects to annual rates of recruitment or survival (i.e., population-level effects). An estimate of the number of Level B harassment takes, alone, is not enough information on which to base an impact determination. In addition to considering estimates of the number of marine mammals that might be "taken" through harassment, NMFS must consider other factors, such as the nature of any responses (their intensity, duration, etc.), the context of any responses (critical reproductive time or location, migration, etc.), or any of the other variables mentioned in the first paragraph (if known), as well as the number and nature of estimated Level A takes, the number of estimated mortalities, and effects on habitat. Generally speaking, Navy and NMFS anticipate more severe effects from takes resulting from exposure to higher received levels (though this is in no way a strictly linear relationship throughout species, individuals, or circumstances) and less severe effects from takes resulting from exposure to lower received levels.

It is worth noting that Navy and NMFS would expect an animal exposed to the levels at the bottom of the risk function to exhibit behavioral responses that are less likely to adversely affect the longevity, survival, or reproductive success of the animals that might be exposed, based on received level, and the fact that the exposures will occur in the absence of some of the other contextual variables that would likely be associated with increased severity of effects, such as the proximity of the sound source(s) or the proximity of other vessels, aircraft, submarines, etc. maneuvering in the vicinity of the exercise. NMFS will consider all available information (other variables, etc.), but all else being equal, takes that result from exposure to lower received levels and at greater distances from the exercises would be less likely to contribute to population level effects.

6.2.4 Navy Protocols For Acoustic Modeling Analysis of Marine Mammal Exposures

Previous variations of the Navy's acoustic impact model allowed for significant overestimation of potential exposures based on a series of assumptions that now have more precise resolution. Specifically in the past, the model overestimated effects because:

- Acoustic footprints for sonar sources near land were not reduced to account for the land mass where marine mammals would not occur.

- Acoustic footprints for sonar sources were added independently and, therefore, did not account for overlap they would have with other sonar systems used during the same active sonar activity. As a consequence, the area of the total acoustic footprint was larger than the actual acoustic footprint when multiple ships are operating together.

- Acoustic exposures do not reflect implementation of mitigation measures, such as reducing sonar source levels when marine mammals are present.

- Marine mammal densities were averaged across specific active sonar activity areas and, therefore, are evenly distributed without consideration for animal grouping or patchiness.

- Acoustic modeling did not account for limitations of the NMFS-defined refresh rate of 24 hours. This time period represents the amount of time in which individual marine mammals can be harasses no more than once.

6.3 Estimated Effects Modeling

Modeling of the effects of mid-frequency sonar and underwater detonations was conducted using methods described in brief below. A detailed description of the representative modeling areas, sound sources, model assumptions, acoustic and oceanographic parameters, underwater sound propagation and transmission models, and diving behavior of species modeled are presented in Appendix B.

6.3.1.1 Acoustic Source Modeling

The approach for estimating potential acoustic effects from NWTRC ASW training activities on cetacean species makes use of the methodology that was developed in cooperation with NOAA for the Navy's Undersea Warfare Exercise (USWEX) Environmental Assessment/Overseas Environmental assessment (EA/OEA) (DoN 2007), RIMPAC EA/OEA (2006) and Composite Training Unit Exercise/Joint Task Force Exercise (COMPTUEX/JTFEX) EA/OEA (2007), as well as additional cooperative work with NMFS for analyzing behavioral effects to marine mammals using the risk-function methodology (DoN 2008). The methodology is provided here to determine the number and species of marine mammals for which incidental take authorization is requested.

In order to estimate acoustic effects from the NWTRC ASW training activities, acoustic sources to be used were examined with regard to their operational characteristics. Sources were examined using simple spreadsheet calculations to ensure that they did not need to be considered further. For example, if a sonobuoy's typical use yielded an exposure area that produced no marine mammal exposures based on the maximum marine mammal density that sonobuoy as a

source was designated non-problematic and was not modeled in the sense of running its parameters through the environmental model (CASS), generating an acoustic footprint, etc.

In addition, systems with an operating frequency greater than 100 kHz were not analyzed in the detailed modeling as these signals attenuate rapidly (due to the frequency) resulting in very short propagation distances for a received level exceeding the acoustic thresholds of concern. There are no ASW sonars transmitting sound underwater in excess of 50 kHz in use by the Navy in the NWTRC Study Area.

Based on the information above, only hull-mounted MFA tactical sonar, DICASS sonobuoy, MK-48 torpedo (HFA sonar), and AN/AQS 22 (dipping sonar) were determined to have the potential to affect marine mammals protected under the MMPA and ESA during NWTRC ASW training events.

For modeling purposes, sonar parameters (source levels, ping length, the interval between pings, output frequencies, etc.) were based on records from training events, previous exercises, and preferred ASW tactical doctrine to reflect the sonar use expected to occur during events in the NWTRC. The actual sonar parameters such as output settings, distance between ASW surface, subsurface, and aerial units, their deployment patterns, and the coordinated ASW movement (speed and maneuvers) across the exercise area are classified, however, modeling used to calculate exposures to marine mammals employed actual and preferred parameters to which the participants are trained and have in the past, used during ASW events in the NWTRC.

For discussion purposes surface ship sonars can be considered as having the nominal source level of 235 dB re 1 μPa^2-s @ 1 m, transmitting a 1 second omnidirectional ping at center frequencies of 2.6 kHz and 3.3 kHz, with 30 seconds between pings.

Every active sonar training activity includes the potential to harass marine animals in the vicinity of the source. The number of animals exposed to potential harassment in any such action is dictated by the propagation field and the manner in which the sonar is operated (i.e., source level, depth, frequency, pulse length, directivity, platform speed, repetition rate).

6.3.1.2 Modeling Physiological Effects

For the NWTRC, the relevant measure of potential physiological effects to marine mammals due to sonar training is the accumulated (summed over all source emissions) energy flux density level received by the animal over the duration of the activity.

The modeling for estimating received energy flux density level from surface ship active tactical sonar occurred in five broad steps, listed below. Results were calculated based on the typical ASW activities planned for the NWTRC.

- **Step 1**. Environmental Seasons. The NWTRC study area is divided into two seasons, dry season and wet season and each has a unique combination of environmental conditions.

- **Step 2**. Transmission Loss. Since sound propagates differently in these nine environments, separate transmission loss calculations must be made for each, in both seasons. The transmission loss is predicted using Comprehensive Acoustic System Simulation Gaussian Ray Bundle (CASS-GRAB) sound modeling software.

- **Step 3**. Exposure Volumes. The transmission loss, combined with the source characteristics, gives the energy field of a single ping. The energy of over 10 hours of

pinging is summed, carefully accounting for overlap of several pings, so an accurate average exposure of an hour of pinging is calculated for each depth increment. Repeating this calculation for each environment in each season gives the hourly ensonified volume, by depth, for each environment and season.

- **Step 4**. Marine Mammal Densities. The marine mammal densities were given in two dimensions, but using sources such as the North Pacific Acoustic Laboratory EIS, the depth regimes of these marine mammals are used to project the two dimensional densities into three dimensions.

- **Step 5**. Exposure Calculations. Each marine mammal's three dimensional density is multiplied by the calculated impact volume—to that marine mammal depth regime. This is the number of exposures per hour for that particular marine mammal. In this way, each marine mammal's exposure count per hour is based on its density, depth habitat, and the ensonified volume by depth. Calculated exposures above 0.5 were counted as one exposure.

The movement of various units during an ASW event is largely unconstrained and dependent on the developing tactical situation presented to the commander of the forces.

Only when all exposures for all training are summed for the year does the model indicate the potential for exposure in excess of 215 dB re 1 μPa^2-s. This summation for the year results in 0.66 of an exposure (rounded up to one (1)) counting as one incident of exposure for humpback whale and 0.53 of an exposure counted as one exposure for striped dolphin. However, the likelihood of exposures above the thresholds for Level A harassment is considered highly improbable. In addition, mitigation measures that will be implemented during the proposed activities would reduce the potential for these two Level A exposures to occur.

6.3.1.3 Modeling Behavioral Effects

For the NWTRC, the relevant measure of potential behavioral disturbance effects to marine mammals due to sonar training is the maximum sound pressure level (SPL) received by the animal over the duration of the activity (or over each day).

The modeling for estimating received energy flux density from surface ship active tactical sonar is analogous to the modeling for energy flux density level, discussed above. However, the SPL metric yields the maximum SPL (and not the sum of energies).

Results were calculated based on the typical ASW activities planned for the NWTRC. Acoustic propagation and mammal population data are analyzed for both the dry season (December to June) and wet season (July to November; See Appendix A for modeling protocol).

6.3.1.3.1 Explosive Source Criteria

The criterion for mortality for marine mammals used in the *CHURCHILL FEIS* (DoN 2001) is "onset of severe lung injury." This is conservative in that it corresponds to a 1 percent chance of mortal injury, and yet any animal experiencing onset severe lung injury is counted as a lethal exposure. The dual criteria are used for injury: onset of slight lung hemorrhage and 50 percent eardrum rupture (tympanic membrane [TM] rupture). These criteria are considered indicative of the onset of injury (Table 6-1). The dual criteria is considered for non-injurious harassment (TTS), which is a temporary, recoverable, loss of hearing sensitivity (NMFS 2001; DoN 2001a).

The third criterion is used for estimation of behavioral disturbance before TTS (sub-TTS) for cases with multiple successive explosions (having less than 2 seconds separation between explosions). The threshold is 177 dB re 1 μPa^2-s (EL) to account for behavioral effects significant enough to be judged as harassment, but occurring at lower sound energy levels than those that may cause TTS. Since there may be rare occasions when multiple explosions in succession (separated by less than 2 seconds) occur during BOMBEX, GUNEX, and NSFS using other than inert rounds, the Churchill approach was extended to cover multiple exposure events at the same location. For multiple exposures, accumulated energy over the entire training time is the natural extension for energy thresholds since energy accumulates with each subsequent shot; this is consistent with the treatment of multiple arrivals in Churchill. For analysis in the NWTRC EIS/OEIS, therefore, given that multiple successive explosions are rare, in consideration of range clearance procedures designed to preclude the presence of marine species within the target area, and because previous modeling efforts have not resulted in expected exposures at the sub-TTS threshold level, modeling for these rare live fire events (BOMBEX, GUNEX, and NSFS) was not undertaken. Additional detail on criteria and thresholds for explosive source effects can be found in Section 6.1.4.

6.3.1.3.2 Explosive Source and Live Fire Procedures

As part of the official Navy clearance procedure before an underwater detonation or live fire exercise, the target area must be inspected visually (from vessels and available aircraft) and determined to be clear. The required clearance zone at the target areas, and training activities within controlled ranges, minimizes the risk to marine mammals. Open ocean clearance procedures are the same for live or inert ordnance. Whenever ships and aircraft use the ranges for missile and gunnery practice, the weapons are used under controlled circumstances involving clearance procedures to ensure cetaceans, pinnipeds, or sea turtles are not present in the target area. These involve, at a minimum, a detailed visual search of the target area by aircraft reconnaissance, range safety boats, and range controllers and passive acoustic monitoring.

Ordnance cannot be released until the target area is determined clear. Training activities are immediately halted if cetaceans, pinnipeds, or sea turtles are observed within the target area. Training activities are delayed until the animal clears the target area. All observers are in continuous communication in order to have the capability to immediately stop the training activities. The procedures can be modified as necessary to obtain a clear target area. If the area cannot be cleared, the event is canceled. All of these factors serve to avoid the risk of harming cetaceans, pinnipeds, or sea turtles. Post event monitoring of underwater detonations have not observed any injured marine mammals.

The weapons used in most missile and live fire exercises pose little risk to marine mammals unless they were to be near the surface at the point of impact. Machine guns (0.50 caliber), 5-in guns, 76mm guns, and close-in weapons systems (anti missile systems) exclusively fire non-explosive ammunition. The same applies to larger weapons firing inert ordnance for training activities. The rounds pose an extremely low risk of a direct hit and potential to directly affect a marine species. Target area clearance procedures would again reduce this risk.

A SINKEX uses a variety of live fire weapons; many of these are guided "smart" weapons. The intention is for the ordnance to hit the target vessel and not the water. Target area clearance procedures would again reduce this risk. Modeling results of the potential exposures of marine

mammals to underwater sound from a SINKEX is included in the summary presented in Table 6-8.

- The Navy has developed a mitigation plan to maximize the probability of sighting any ships or protected species in the vicinity of a training activity. In order to minimize the likelihood of taking any threatened or endangered species that may be in the area, the following monitoring plan would be adhered to:

- All weapons firing would be conducted during the period 1 hour after official sunrise to 30 minutes before official sunset.

- Extensive range clearance procedures would be conducted in the hours prior to commencement of the training, ensuring that no shipping is located within the hazard range of the longest-range weapon being fired for that event.

An exclusion zone with a radius of 1 nm would be established around each target. This exclusion zone is based on calculations using a 990 lb net explosive weight high explosive source detonated 5 feet below the surface of the water, which yields a distance of 0.85 nm (cold season) and 0.89 nm (warm season) beyond which the received level is below the 182 dB re: 1 μPa^2-s threshold established for the *WINSTON S. CHURCHILL* (DDG 81) shock trials. An additional buffer of 0.5 nm would be added to account for errors, target drift, and animal movements. Additionally, a safety zone, which extends from the exclusion zone at 1 nm out an additional 0.5 nm, would be surveyed. Together, the zones extend out 2 nm from the target.

- A series of surveillance over-flights would be conducted within the exclusion and the safety zones, prior to and during the training, when feasible. Survey protocol would be as follows:

- All visual surveillance training activities would be conducted by Navy personnel trained in visual surveillance. In addition to the over flights, the exclusion zone would be monitored by passive acoustic means, when assets are available.

If a protected species observed within the exclusion zone is diving, firing would be delayed until the animal is re-sighted outside the exclusion zone, or 30 minutes has elapsed. After 30 minutes, if the animal has not been re-sighted it would be assumed to have left the exclusion zone. This is based on a typical dive time of 30 minutes for traveling listed species of concern. The officer-in-charge of the exercise (OCE) would determine if the ESA listed species is in danger of being adversely affected by commencement of the training activity.

6.3.2 Other Effects Considered

6.3.2.1 Stress

A possible stressor for marine mammals exposed to sound, including mid-frequency active sonar, is the effect on health and physiological stress (Review by Fair and Becker 2000). A stimulus may cause a number of behavioral and physiological responses such as an elevated heart rate, increases in endocrine and neurological function, and decreased immune function, particularly if the animal perceives the stimulus as life threatening (Seyle 1950; Moberg 2000; Sapolsky *et al.* 2005). The primary response to the stressor is to move away to avoid continued exposure. Next, the animal's physiological response to a stressor is to engage the autonomic nervous system with the classic "fight or flight" response. This includes changes in the cardiovascular system (increased heart rate), the gastrointestinal system (decrease digestion), the

exocrine glands (increased hormone output), and the adrenal glands (increased nor-epinephrine). These physiological and hormonal responses are short lived and may not have significant long-term effects on an animal's health or fitness. Generally these short term responses are not detrimental to the animal except when the health of the animal is already compromised by disease, starvation or parasites; or the animal is chronically exposed to a stressor.

Exposure to chronic or high intensity sound sources can cause physiological stress. Acoustic exposures and physiological responses have been shown to cause stress responses (elevated respiration and increased heart rates) in humans (Jansen 1998). Jones (1998) reported on reductions in human performance when faced with acute, repetitive exposures to acoustic disturbance. Trimper et al. (1998) reported on the physiological stress responses of osprey to low-level aircraft noise. Krausman et al. (2004) reported on the auditory (TTS) and physiology stress responses of endangered Sonoran pronghorn to military overflights. Smith et al. (2004a, 2004b) recorded sound-induced physiological stress responses in a hearing-specialist fish that was associated with TTS. Welch and Welch (1970) reported physiological and behavioral stress responses that accompanied damage to the inner ears of fish and several mammals.

Most of these responses to sound sources or other stimuli have been studied extensively in terrestrial animals but are much more difficult to determine in marine mammals. Increases in heart rate are common reaction to acoustic disturbance in marine mammals (Miksis *et al.* 2001) as are small increases in the hormones norepinephrine, epinephrine, and dopamine (Romano *et al.* 2002; 2004). Increases in cortical steroids are more difficult to determine because blood collection procedures will also cause stress (Romano *et al.* 2002; 2004). A recent study, Chase Encirclement Stress Studies (CHESS), was conducted by NMFS on chronic stress effects in small odontocetes affected by the eastern tropical Pacific tuna fishery (Forney et al. 2002). Analysis was conducted on blood constituents, immune function, reproductive parameters, heart rate and body temperature of small odontocetes that had been pursued and encircled by tuna fishing boats. Some effects were noted, including lower pregnancy rates, increases in norepinephrine, dopamine, ACTH and cortisol levels, heart lesions and an increase in fin and surface temperature when chased for over 75 minutes but with no change in core body temperature (Forney et al. 2002). These stress effects in small cetaceans that were actively pursued (sometimes for over 75 minutes) were relatively small and difficult to discern. It is unlikely that marine mammals exposed to mid-frequency active sonar would be exposed at long as the cetaceans in the CHESS study and would not be pursued by the Navy ships, therefore stress effects would be minimal from the short term exposure to sonar.

6.3.2.2 Acoustically Mediated Bubble Growth

One suggested cause of injury to marine mammals is by rectified diffusion (Crum and Mao 1996) the process of increasing the size of a bubble by exposing it to a sound field. This process is facilitated if the environment in which the ensonified bubbles exist is supersaturated with a gas, such as nitrogen which makes up approximately 78 percent of air (remainder of air is about 21 percent oxygen with some carbon dioxide). Repetitive diving by marine mammals can cause the blood and some tissues to accumulate gas to a greater degree than is supported by the surrounding environmental pressure (Ridgway and Howard 1979). Deeper and longer dives of some marine mammals (for example, beaked whales) are theoretically predicted to induce greater super saturation (Houser et al. 2001). Conversely, studies have shown that marine mammal lung structure (both pinnipeds and cetaceans) facilitates collapse of the lungs at depths deeper than approximately 162 ft (50 m) (Kooyman et al. 1970). Collapse of the lungs would

force air in to the non-air exchanging areas of the lungs (in to the bronchioles away from the alveoli) thus significantly decreasing nitrogen diffusion in to the body. Deep diving pinnipeds such as the northern elephant and Weddell seals (*Leptonychotes weddellii*) typically exhale before long deep dives, further reducing air volume in the lungs (Kooyman et al. 1970). If rectified diffusion were possible in marine mammals exposed to high-level sound, conditions of tissue super saturation could theoretically speed the rate and increase the size of bubble growth. Subsequent effects due to tissue trauma and emboli would presumably mirror those observed in humans suffering from decompression sickness.

It is unlikely that the short duration of sonar pings would be long enough to drive bubble growth to any substantial size, if such a phenomenon occurs. However, an alternative but related hypothesis has also been suggested. Stable bubbles could be destabilized by high-level sound exposures such that bubble growth then occurs through static diffusion of gas out of the tissues. In such a scenario the marine mammal would need to be in a gas-supersaturated state for a long enough period of time and exposed to a continuous sound source for bubbles to become of a problematic size.

6.3.2.3 Decompression Sickness

Another hypothesis suggests that rapid ascent to the surface following exposure to a startling sound might produce tissue gas saturation sufficient for the evolution of nitrogen bubbles (Jepson et al. 2003). In this scenario, the rate of ascent would need to be sufficiently rapid to compromise behavioral or physiological protections against nitrogen bubble formation. Cox et al. (2006) with experts in the field of marine mammal behavior, diving, physiology, respiration physiology, pathology, anatomy, and bio-acoustics considered this to be a plausible hypothesis but requires further investigation. Rommel et al. (2006) reviewed beaked whale anatomy and diving physiology in relation to strandings and concluded that "" It is important to note that no current hypothesis of pathogenic mechanisms resulting in acoustically-related strandings is proven." Conversely Fahlman et al. (2006) suggested that diving bradycardia (reduction in heart rate and circulation to the tissues), lung collapse and slow ascent rates would reduce nitrogen uptake and thus reduce the risk of decompression sickness by 50 percent in models of marine mammals. Zimmer and Tyack (2007) suggest that beaked whales avoid sonar sound by swimming deeper than 25 m and shallower than the depth of alveolar collapse. This avoidance mechanism continues until the sound no longer creates the response or the animal enters shallow water where it can no longer dive in this pattern. This hypothesis could lead to decompression sickness and is consistent with previous studies on avoidance, for example with ship noise (Zimmer and Tyack, 2007). Recent information on the diving profiles of Cuvier's (*Ziphius cavirostris*) and Blainvilles's (*Mesoplodon densirostris*) beaked whales (Baird et al. 2006) and in the Ligurian Sea in Italy (Tyack et al. 2006) showed that while these species do dive deeply (regularly exceed depths of 800 m [2,625 ft]) and for long periods (48-68 minutes), they have significantly slower ascent rates than descent rates. This fits well with Fahlman et al. (2006) model of deep and long duration divers that would have slower ascent rates to reduce nitrogen saturation and reduce the risk of decompression sickness. Therefore, if nitrogen saturation remains low, then a rapid ascent in response to sonar should not cause decompression sickness. Currently it is not known if beaked whales rapidly ascend in response to sonar or other disturbances. It may be that deep diving animals would be better protected diving to depth to avoid predators, such as killer whales, rather then ascending to the surface where they may be more susceptible to predators.

Although theoretical predictions suggest the possibility for acoustically mediated bubble growth, there is considerable disagreement among scientists as to its likelihood (Piantadosi and Thalmann, 2004; Evans and Miller, 2004). To date, ELs predicted to cause *in vivo* bubble formation within diving cetaceans have not been evaluated (NOAA, 2002b). Further, although it has been argued that traumas from recent beaked whale strandings are consistent with gas emboli and bubble-induced tissue separations (Jepson et al. 2003), there is no conclusive evidence of this and complicating factors associated with introduction of gas in to the venous system during necropsy. Because evidence supporting it is debatable, no marine mammals addressed in this LOA are given special treatment due to the possibility for acoustically mediated bubble growth.

6.3.2.4 Resonance

Another suggested cause of injury in marine mammals is air cavity resonance due to sonar exposure. Resonance is a phenomenon that exists when an object is vibrated at a frequency near its natural frequency of vibration—the particular frequency at which the object vibrates most readily. The size and geometry of an air cavity determine the frequency at which the cavity will resonate. Displacement of the cavity boundaries during resonance has been suggested as a cause of injury. Large displacements have the potential to tear tissues that surround the air space (for example, lung tissue).

Understanding resonant frequencies and the susceptibility of marine mammal air cavities to resonance is important in determining whether certain sonars have the potential to affect different cavities in different species. In 2002, NMFS convened a panel of government and private scientists to address this issue (NOAA 2002b). They modeled and evaluated the likelihood that Navy mid-frequency active sonar caused resonance effects in beaked whales that eventually led to their stranding (Department of Commerce and DoN 2001). The conclusions of that group were that resonance in air-filled structures the frequencies at which resonance were predicted to occur were below the frequencies utilized by the sonar systems employed. Furthermore, air cavity vibrations due to the resonance effect were not considered to be of sufficient amplitude to cause tissue damage.

6.3.2.5 Likelihood of Prolonged Exposure

The proposed ASW activities within the NWTRC would not result in prolonged exposure because the vessels are constantly moving, and the flow of the activity in the NWTRC when ASW training occurs reduces the potential for prolonged exposure. The implementation of the mitigation measures described in Section 11 would further reduce the likelihood of any prolonged exposure.

6.3.2.6 Likelihood of Masking

Natural and artificial sounds can disrupt behavior by masking, or interfering with an animal's ability to hear other sounds. Masking occurs when the receipt of a sound is interfered with by a second sound at similar frequencies and at similar or higher levels. If the second sound were artificial, it could be potentially harassing if it disrupted hearing-related behavior such as communications or echolocation. It is important to distinguish TTS and PTS, which persist after the sound exposure, from masking, which occurs during the sound exposure.

Historically, principal masking concerns have been with prevailing background sound levels from natural and manmade sources (for example, Richardson et al. 1995). Dominant examples

of the latter are the accumulated sound from merchant ships and sound of seismic surveys. Both cover a wide frequency band and are long in duration.

The proposed NWTRC ASW areas are away from harbors but may include heavily traveled shipping lanes, although shipping lanes are a small portion of the overall range complex. The loudest mid-frequency underwater sounds in the Proposed Action area are those produced by hull-mounted mid-frequency active tactical sonar. The sonar signals are likely within the audible range of most cetaceans, but are very limited in the temporal and frequency domains. In particular, the pulse lengths are short, the duty cycle low, the total number of hours of operation per year small, and these hull-mounted mid-frequency active tactical sonars transmit within a narrow band of frequencies (typically less than one-third octave).

For the reasons outlined above, the chance of sonar activities causing masking effects is considered negligible.

6.3.2.7 Long-Term Effects

Navy activities are conducted in the same general areas throughout the NWTRC, so marine mammal populations could be exposed to repeated activities over time. However, as described earlier, short-term non-injurious sound exposure levels predicted to cause TTS or temporary behavioral disruptions qualify as MMPA Level B harassment. Application of this criterion assumes an effect even though it is highly unlikely that all behavioral disruptions or instances of TTS will result in long term significant impacts.

Long-term monitoring programs for the NWTRC are being developed by the Navy to assess population trends and responses of marine mammals to Navy activities. Short-term monitoring programs for exercises (e.g., Undersea Warfare Exercise (USWEX)) are being developed to assess mitigation measures and responses of marine mammals to Navy activities.

6.3.3 Application of Exposure Thresholds to Other Species

6.3.3.1 Mysticetes

Information on auditory function in mysticetes is extremely lacking. Sensitivity to low-frequency sound by baleen whales has been inferred from observed vocalization frequencies, observed reactions to playback of sounds, and anatomical analyses of the auditory system. Baleen whales are estimated to hear from 15 Hz to 20 kHz, with good sensitivity from 20 Hz to 2 kHz (Ketten 1998). Filter-bank models of the humpback whale's ear have been developed from anatomical features of the humpback's ear and optimization techniques (Houser et al. 2001). The results suggest that humpbacks are sensitive to frequencies between 40 Hz and 16 kHz, but best sensitivity is likely to occur between 100 Hz and 8 kHz. However, absolute sensitivity has not been modeled for any baleen whale species. Furthermore, there is no indication of what sorts of sound exposure produce threshold shifts in these animals.

The criteria and thresholds for PTS and TTS developed for odontocetes for this activity are also used for mysticetes. This generalization is based on the assumption that the empirical data at hand are representative of both groups until data collection on mysticete species shows otherwise. For the frequencies of interest for this action, there is no evidence that the total amount of energy required to induce onset-TTS and onset-PTS in mysticetes is different than that required for odontocetes.

6.3.3.2 Beaked Whales

Recent beaked whale strandings have prompted inquiry into the relationship between high-amplitude continuous-type sound and the cause of those strandings. For example, in the stranding in the Bahamas in 2000, the Navy mid-frequency sonar was identified as the only contributory cause that could have lead to the stranding. The Bahamas exercise entailed multiple ships using mid-frequency sonar during transit of a long constricted channel. The Navy participated in an extensive investigation of the stranding with the NMFS. The "Joint Interim Report, Bahamas Marine Mammal Stranding Event of 15-16 March 2000" concluded that the variables to be considered in managing future risk from tactical mid-range sonar were "sound propagation characteristics (in this case a surface duct), unusual underwater bathymetry, intensive use of multiple sonar units, a constricted channel with limited egress avenues, and the presence of beaked whales that appear to be sensitive to the frequencies produced by these sonars." (Department of Commerce and DoN 2001).

The Navy analyzed the known range of operational, biological, and environmental factors involved in the Bahamas stranding and focused on the interplay of these factors to reduce risks to beaked whales from ASW training activities. The confluence of these factors do not occur in the NWTRC. Although beaked whales are visually and acoustically detected in areas where sonar use routinely takes place, there has not been a stranding of beaked whales in the NWTRC associated with the 30-year use history of the present sonar systems.

This history would suggest that the simple exposure of beaked whales to sonar is not enough to cause beaked whales to strand. Brownell et al (2004), have suggested that the high number of beaked whale strandings in Japan between 1980 and 2004 may be related to U.S. Navy sonar use in those waters given the presence of U.S. Naval Bases and exercises off Japan. The Center for Naval Analysis compiled the history of naval exercises taking place off Japan and found there to be no correlation in time for any of the stranding events presented in Brownell et al (2004). Like the situation in California, there are clearly beaked whales present in the waters off Japan (as evidenced by the strandings) however, there is no correlation in time to strandings and sonar use. Sonar did not causing the strandings provided by Brownell et al. (2004) and more importantly, this suggests sonar use in the presence of beaked whales over two decades has not resulted in strandings related to sonar use.

As suggested by the known presence of beaked whales in waters sonar use has historically taken place, it is likely that beaked whales have been occasionally exposed to sonar during the last 30 years of sonar use in northern California, Oregon, and Washington waters and yet there is no indication of any adverse impact on beaked whales from exposure to sonar. Therefore, the continued use of sonar in the NWTRC is not likely to result in effects to beaked whales.

6.4 Cetacean Strandings and Threats

The Navy is very concerned about and thoroughly investigates each stranding potentially associated with Navy sonar use to better understand these interactions. Strandings can be a single animal or several to hundreds. An event where animals are found out of their normal habitat is considered a stranding even though animals do not necessarily end up beaching (such as the July 2004 Hanalei Mass Stranding Event; Southall et al. 2006). Several hypotheses have been given for the mass strandings which include the impact of shallow beach slopes on odontocete sonar, disease or parasites, geomagnetic anomalies that affect navigation, following a food source in

close to shore, avoiding predators, social interactions that cause other cetaceans to come to the aid of stranded animals, and human actions. Generally, inshore species do not strand in large numbers but generally just as a single animal. This may be due to their familiarity with the coastal area whereas pelagic species that are unfamiliar with obstructions or sea bottom tend to strand more often in larger numbers (Woodings 1995). The Navy has studied several stranding events in detail that may have occurred in association with Navy sonar activities. To better understand the causal factors in stranding events that may be associated with Navy sonar activities, the main factors, including bathymetry (i.e., steep drop offs), narrow channels (less than 35 nm [65 km]), environmental conditions (e.g., surface ducting), and multiple sonar ships (see Section on Stranding Events Associated with Navy Sonar) were compared between the different stranding events.

In a review of 70 reports of mass stranding events between 1960 and 2006, 48 (68 percent) involved beaked whales, three (four percent) involved dolphins, and 14 (20 percent) involved whale species. Cuvier's beaked whales were involved in the greatest number of these events (48 or 68 percent), followed by sperm whales (seven or ten percent), and Blainville's and Gervais' beaked whales (four each or six percent). Naval training activities that might have involved tactical sonars are reported to have coincided with nine (13 percent) or ten (14 percent) of those stranding events. Between the mid-1980s and 2003 (the period reported by the IWC 2007), the Navy identified reports of 44 mass cetacean stranding events of which at least seven have been correlated with naval training activities that were using MFA sonar.

6.4.1 What is a Stranded Marine Mammal?

When a live or dead marine mammal swims or floats onto shore and becomes "beached" or incapable of returning to sea, the event is termed a "stranding" (Geraci et al. 1999; Perrin and Geraci, 2002; Geraci and Lounsbury, 2005; NMFS, 2007). The legal definition for a stranding within the US is that "(A) a marine mammal is dead and is (i) on a beach or shore of the United States; or (ii) in waters under the jurisdiction of the United States (including any navigable waters); or (B) a marine mammal is alive and is (i) on a beach or shore of the United States and is unable to return to the water; (ii) on a beach or shore of the United States and, although able to return to the water, is in need of apparent medical attention; or (iii) in the waters under the jurisdiction of the United States (including any navigable waters), but is unable to return to its natural habitat under its own power or without assistance." (16 United States Code [U.S.C.] 1421h).

The majority of animals that strand are dead or moribund (NMFS, 2007). For those that are alive, human intervention through medical aid and/or guidance seaward may be required for the animal to return to the sea. If unable to return to sea, rehabilitation at an appropriate facility may be determined as the best opportunity for animal survival. An event where animals are found out of their normal habitat is may be considered a stranding depending on circumstances even though animals do not necessarily end up beaching (Southhall 2006).

Three general categories can be used to describe strandings: single, mass, and unusual mortality events. The most frequent type of stranding is a single stranding, which involves only one animal (or a mother/calf pair) (NMFS, 2007).

Mass stranding involves two or more marine mammals of the same species other than a mother/calf pair (Wilkinson, 1991), and may span one or more days and range over several miles (Simmonds and Lopez-Jurado, 1991; Frantzis, 1998; Walsh et al. 2001; Freitas, 2004). In North

America, only a few species typically strand in large groups of 15 or more and include sperm whales, pilot whales, false killer whales, Atlantic white-sided dolphins, white-beaked dolphins, and rough-toothed dolphins (Odell, 1987; Walsh et al. 2001). Some species, such as pilot whales, false-killer whales, and melon-headed whales occasionally strand in groups of 50 to 150 or more (Geraci et al. 1999). All of these normally pelagic off-shore species are highly sociable and usually infrequently encountered in coastal waters. Species that commonly strand in smaller numbers (e.g., one to several individuals) include pygmy killer whales, common dolphins, bottlenose dolphins, Pacific white-sided dolphin, Frasier's dolphins, gray whale and humpback whale (West Coast only), harbor porpoise, Cuvier's beaked whales, California sea lions, and harbor seals (Mazzuca et al. 1999; Norman et al. 2004; Geraci and Lounsbury, 2005).

Unusual mortality events (UMEs) can be a series of single strandings or mass strandings, or unexpected mortalities (i.e., die-offs) that occur under unusual circumstances (Dierauf and Gulland, 2001; Harwood, 2002; Gulland, 2006; NMFS, 2007). These events may be interrelated: for instance, at-sea die-offs lead to increased stranding frequency over a short period of time, generally within one to two months. As published by the NMFS, revised criteria for defining a UME include (Hohn et al. 2006b):

(1) A marked increase in the magnitude or a marked change in the nature of morbidity, mortality, or strandings when compared with prior records.

(2) A temporal change in morbidity, mortality, or strandings is occurring.

(3) A spatial change in morbidity, mortality, or strandings is occurring.

(4) The species, age, or sex composition of the affected animals is different than that of animals that are normally affected.

(5) Affected animals exhibit similar or unusual pathologic findings, behavior patterns, clinical signs, or general physical condition (e.g., blubber thickness).

(6) Potentially significant morbidity, mortality, or stranding is observed in species, stocks or populations that are particularly vulnerable (e.g., listed as depleted, threatened or endangered or declining). For example, stranding of three or four right whales may be cause for great concern whereas stranding of a similar number of fin whales may not.

(7) Morbidity is observed concurrent with or as part of an unexplained continual decline of a marine mammal population, stock, or species.

UMEs are usually unexpected, infrequent, and may involve a significant number of marine mammal mortalities. As discussed below, unusual environmental conditions are probably responsible for most UMEs and marine mammal die-offs (Vidal and Gallo-Reynoso 1996; Geraci et al. 1999; Walsh et al. 2001; Gulland and Hall 2005).

United States Stranding Response Organization

Stranding events provide scientists and resource managers information not available from limited at-sea surveys, and may be the only way to learn key biological information about certain species such as distribution, seasonal occurrence, and health (Rankin, 1953; Moore et al. 2004; Geraci and Lounsbury, 2005). Necropsies are useful in attempting to determine a reason for the stranding, and are performed on stranded animals when the situation and resources allow.

In 1992, Congress passed the Marine Mammal Health and Stranding Response Act (MMHSRA) which authorized the Marine Mammal Health and Stranding Response Program (MMHSRP) under authority of the Department of Commerce, NMFS. The MMHSRP was created because of public concern over marine mammal mortalities. Its objectives are twofold: to formalize the response process and to focus efforts being initiated by numerous local stranding organizations.

Major elements of the MMHSRP include (NMFS, 2007):

- National Marine Mammal Stranding Network
- Marine Mammal UME Program
- National Marine Mammal Tissue Bank (NMMTB) and Quality Assurance Program
- Marine Mammal Health Biomonitoring, Research, and Development
- Marine Mammal Disentanglement Network
- John H. Prescott Marine Mammal Rescue Assistance Grant Program (a.k.a. the Prescott Grant Program)
- Information Management and Dissemination.

The United States has a well-organized network in coastal states to respond to marine mammal strandings. Overseen by the NMFS, the National Marine Mammal Stranding Network (NMMSN) is comprised of smaller organizations manned by professionals and volunteers from nonprofit organizations, aquaria, universities, and state and local governments trained in stranding response. Currently, more than 141 organizations are authorized by NMFS to respond to marine mammal strandings (NMFS 2007). Through a National Coordinator and six regional coordinators, NMFS authorizes and oversees stranding response activities and provides specialized training for the network.

Stranding reporting and response efforts over time have been inconsistent, although effort and data quality within the US have been improving within the last 20 years. Given the historical inconsistency in response and reporting, however, interpretation of long-term trends in marine mammal stranding is difficult. During the past decade (1995 – 2004), approximately 40,000 stranded marine mammals (about 12,400 were cetaceans) have been reported by the regional stranding networks, averaging 3,600 reported strandings per year (Fig. 4-3; NMFS, 2007). The highest number of strandings were reported between the years 1998 and 2003. Detailed regional stranding information including most commonly stranded species can be found in Zimmerman (1991), Geraci and Lounsbury (2005), and NMFS (2007).

6.4.1.1 *Stranding Data*

Stranding events, though unfortunate, can be useful to scientists and resource managers because they can provide information that is not accessible at sea or through any other means. Necropsies are useful in attempting to assess a reason for the stranding, and are performed on stranded animals when the situation allows. Stranded animals have provided us with the opportunity to gain insight into the lives of marine mammals such as their natural history, seasonal distribution, population health, reproductive biology, environmental contaminant levels, types of interactions with humans, and the prevalence of disease and parasites. The only existing information on some cetacean species has been discovered from stranding events (NMFS 2007c).

Currently the government agency that is responsible for responding to strandings is the MMHSRP within NMFS. The NMMSN, which is one part of the more comprehensive MMHSRP, is made up of smaller organizations partnered with NMFS to investigate marine mammal strandings. These stranding networks are established in all coastal states and consist of professionals and volunteers from nonprofit organizations, aquaria, universities, and state and local governments who are trained in stranding response. NMFS authorizes, coordinates, and participates in response activities and personnel training (NMFS 2007c). NMFS oversees stranding response via a National Coordinator and a regional coordinator in each of the NMFS regions. Stranding reporting and response efforts over time have been inconsistent and have been increasing over the past three decades, making any trends hard to interpret (NMFS 2007d). Over the past decade (1990–2000), approximately 40,000 stranded marine mammals have been reported by the regional stranding networks, averaging 3,600 strandings reported per year (NMFS 2007f). The highest number of strandings was reported between the years 1992–1993 and 1997–1998, with a peak in the number of reported strandings in 1998 totaling 5,708 (NMFS 2007f; 2007f). These have since been determined to have been El Niño years, which for a variety of reasons can have a drastic effect on marine mammals (see below). Reporting effort has been more consistent since 1994. Between 1994 and 1998 a total of 19,130 strandings were reported, with an average of 3,826 per year (NMFS 2007d). The composition of animals involved in strandings varied by region.

Peak years for cetacean strandings were in 1994 and 1999, and can be attributed to two UMEs. In 1994, 220 bottlenose dolphins stranded off Texas, which represented almost double the annual average (NMFS 2007f). It has been determined that the probable cause for these strandings was a morbillivirus outbreak. Then in 1999, 223 harbor porpoises stranded from Maine to North Carolina, representing a four-fold increase over the annual average (NMFS 2007f). The most likely cause for these strandings is interspecific aggression due to sea surface temperatures and a shift in prey species in the Mid-Atlantic (NMFS 2007f).

Table 6-4 presents the numbers and composition of reported strandings during the five year period 2001-2005.

**Table 6-4. Summary of the Number of Cetacean and Pinniped
Strandings by Region from 2001-2005**

Region	Number of Cetaceans	Number of Pinnipeds
Pacific	421	357
Southeast	3,549	55
Northeast	2,144	4,744
Southwest	49	230
Northwest	321	1,984
Alaska	152	119
Five-Year Totals	**6,636**	**7,489**

Source: National Marine Fisheries Service, 2007d, 2008

6.4.2 Potential Causes for Stranding

Like any wildlife population, there are normal background mortality rates that influence marine mammal population dynamics, including starvation, predation, aging, reproductive success, and disease (Geraci et al. 1999; Carretta et al. 2007). Strandings may be reflective of this natural

cycle or, more recently, may be the result of anthropogenic sources (i.e., human impacts). Current science suggests that multiple factors, both natural and man-made, may be acting alone or in combination to cause a marine mammal to strand (Geraci et al. 1999; Culik, 2002; Perrin and Geraci, 2002; Hoelzel, 2003; Geraci and Lounsbury, 2005; NRC, 2006). While post-stranding data collection and necropsies of dead animals are attempted in an effort to find a possible cause for the stranding, it is often difficult to pinpoint exactly one factor that is responsible for any given stranding. An animal suffering from one ailment becomes susceptible to various other influences because of its weakened condition, making it difficult to determine a primary cause. In many stranding cases, scientists never learn the exact reason for the stranding.

Specific threats and potential stranding causes may include the following:

- Natural causes

    o Disease
    o Natural toxins
    o Weather and climatic influences
    o Navigation errors
    o Social cohesion
    o Predation

- Anthropogenic (human influenced) causes

    o Fisheries interaction
    o Vessel strike

6.4.2.1 Causes of Natural Stranding

Significant natural causes of mortality, die-offs, and stranding discussed below include disease and parasitism; marine neurotoxins from algae; navigation errors that lead to inadvertent stranding; and climatic influences that impact the distribution and abundance of potential food resources (i.e., starvation). Other natural mortality not discussed in detail includes predation by other species such as sharks (Cockcroft et al. 1989; Heithaus, 2001), killer whales (Constantine et al. 1998; Guinet et al. 2000; Pitman et al. 2001), and some species of pinniped (Hiruki et al. 1999; Robinson et al. 1999).

6.4.2.1.1 Disease

Like other mammals, marine mammals frequently suffer from a variety of diseases of viral, bacterial, and fungal origin (Visser et al. 1991; Dunn et al. 2001; Harwood, 2002). Gulland and Hall (2005) provide a more detailed summary of individual and population effects of marine mammal diseases.

Microparasites such as bacteria, viruses, and other microorganisms are commonly found in marine mammal habitats and usually pose little threat to a healthy animal (Geraci et al. 1999). For example, long-finned pilot whales that inhabit the waters off of the northeastern coast of the US are carriers of the morbillivirus, yet have grown resistant to its usually lethal effects (Geraci et al. 1999). Since the 1980s, however, viral infections have been strongly associated with marine mammal die-offs (Domingo et al. 1992; Geraci and Lounsbury, 2005). Morbillivirus, the most significant identified marine mammal virus, suppresses a host's immune system and increases risk of secondary infection (Harwood, 2002). A bottlenose dolphin UME in 1993 and 1994 was caused by morbillivirus. Die-offs ranged from northwestern Florida to Texas, with an

increased number of deaths as it spread (NMFS, 2007). A 2004 UME in Florida was also associated with dolphin morbillivirus (NMFS, 2004). Influenza A was responsible for a mass mortality in the US, occurring along the coast of New England in 1979-1980 (Geraci et al. 1999; Harwood, 2002). Canine distemper virus has been responsible for large scale pinniped mortalities and die-offs (Grachev et al. 1989; Kennedy et al. 2000; Gulland and Hall, 2005), while a bacteria, Leptospira pomona, is responsible for periodic die-offs in California sea lions about every four years (Gulland et al. 1996; Gulland and Hall, 2005). It is difficult to determine whether microparasites commonly act as a primary pathogen, or whether they show up as a secondary infection in an already weakened animal (Geraci et al. 1999). Most marine mammal die-offs from infectious disease in the last 25 years, however, have had viruses associated with them (Simmonds and Mayer, 1997; Geraci et al. 1999; Harwood, 2002).

Macroparasites are usually large parasitic organisms and include lungworms, trematodes (parasitic flatworms), and protozoans (Geraci and St.Aubin, 1987; Geraci et al. 1999). Marine mammals can carry many different types, and have shown a robust tolerance for sizeable infestation unless compromised by illness, injury, or starvation (Morimitsu et al. 1987; Dailey et al. 1991; Geraci et al. 1999). Nasitrema, a usually benign trematode found in the head sinuses of cetaceans (Geraci et al. 1999), can cause brain damage if it migrates (Ridgway and Dailey, 1972). As a result, this worm is one of the few directly linked to stranding in the cetaceans (Dailey and Walker, 1978; Geraci et al. 1999).

Non-infectious disease, such as congenital bone pathology of the vertebral column (osteomyelitis, spondylosis deformans, and ankylosing spondylitis [AS]), has been described in several species of cetacean (Paterson, 1984; Alexander et al. 1989; Kompanje, 1995; Sweeny et al. 2005). In humans, bone pathology such as AS, can impair mobility and increase vulnerability to further spinal trauma (Resnick and Niwayama, 2002). Bone pathology has been found in cases of single strandings (Paterson, 1984; Kompanje, 1995), and also in cetaceans prone to mass stranding (Sweeny et al. 2005), possibly acting as a contributing or causal influence in both types of events.

6.4.2.1.2 Naturally Occurring Marine Neurotoxins

Some single cell marine algae common in coastal waters, such as dinoflagellates and diatoms, produce toxic compounds that can accumulate (termed bioaccumulation) in the flesh and organs of fish and invertebrates (Geraci et al. 1999; Harwood, 2002). Marine mammals become exposed to these compounds when they eat prey contaminated by these naturally produced toxins (Van Dolah, 2005).

In the Gulf of Mexico and mid- to southern Atlantic states, "red tides," a form of harmful algal bloom, are created by a dinoflagellate (*Karenia brevis*). K. brevis is found throughout the Gulf of Mexico and sometimes along the Atlantic coast (Van Dolah, 2005; NMFS, 2007). It produces a neurotoxin known as brevetoxin. Brevetoxin has been associated with several marine mammal UMEs within this area (Geraci, 1989; Van Dolah et al. 2003; NMFS, 2004; Flewelling et al. 2005; Van Dolah, 2005; NMFS, 2007). On the US west coast and in the northeast Atlantic, several species of diatoms produce a toxin called domoic acid which has also been linked to marine mammal strandings (Bejarano et al. 2007; Geraci et al. 1999; Van Dolah et al. 2003; Greig et al. 2005; Van Dolah, 2005; Brodie et al. 2006; NMFS, 2007).   Other algal toxins associated with marine mammal strandings include saxitoxins and ciguatoxins and are summarized by Van Dolah (2005).

In 2004, between March 10 and April 13, 107 bottlenose dolphins were found dead and stranded on the Florida Panhandle, along with hundreds of dead fish and marine invertebrates (NMFS 2007o). This event was declared a UME. Analyses of the dolphins found brevetoxins at high levels within the dolphin stomach contents, and at variable levels within their tissues (NMFS 2007o). Low levels of domoic acid were also detected in some of the dolphins, and a diatom that produces domoic acid (*Pseudo-nitzschia delicatissima*) was present in low to moderate levels in water samples (NMFS 2007o). In the Gulf of Mexico, two other UMEs associated with red tide involving bottlenose dolphins occurred previously in 1996, and between 1999 and 2000 (NMFS 2005h).

Insufficient information is available to determine how, or at what levels and in what combinations, environmental contaminants may affect cetaceans (Marine Mammal Commission 2003). There is growing evidence that high contaminant burdens are associated with several physiological abnormalities, including skeletal deformations, developmental effects, reproductive and immunological disorders, and hormonal alterations (Reijnders and Aguilar 2002). It is possible that anthropogenic chemical contaminants initially cause immunosuppression, rendering whales susceptible to opportunistic bacterial, viral, and parasitic infection (De Swart et al. 1995).

6.4.2.1.3 Weather events and climate influences

Severe storms, hurricanes, typhoons, and prolonged temperature extremes may lead to localized marine mammal strandings (Geraci et al. 1999; Walsh et al. 2001). Hurricanes may have been responsible for mass strandings of pygmy killer whales in the British Virgin Islands and Gervais' beaked whales in North Carolina (Mignucci-Giannoni et al. 2000; Norman and Mead, 2001). Storms in 1982-1983 along the California coast led to deaths of 2,000 northern elephant seal pups (Le Boeuf and Reiter, 1991). Ice movement along southern Newfoundland has forced groups of blue whales and white-beaked dolphins ashore (Sergeant, 1982). Seasonal oceanographic conditions in terms of weather, frontal systems, and local currents may also play a role in stranding (Walker et al. 2005).

The effect of large scale climatic changes to the world's oceans and how these changes impact marine mammals and influence strandings is difficult to quantify given the broad spatial and temporal scales involved, and the cryptic movement patterns of marine mammals (Moore, 2005; Learmonth et al. 2006). The most immediate, although indirect, effect is possible decreased prey availability during unusual or rapid climate changes. This, in turn, results in increased search effort required by marine mammals (Crocker et al. 2006) and potential starvation if foraging is not successful. Stranding may follow either as a direct result of starvation or as an indirect result of a weakened and stressed state (e.g., succumbing to disease) (Selzer and Payne, 1988; Geraci et al. 1999; Moore, 2005; Learmonth et al. 2006; Weise et al. 2006).

Two recent papers examined potential influences of climate fluctuation on stranding events in southern Australia, including Tasmania, an area with a history of more than 20 mass stranding since the 1920s (Evans et al. 2005; Bradshaw et al. 2006). These authors note that patterns in animal migration, survival, fecundity, population size, and strandings will revolve around the availability and distribution of food resources. In southern Australia, movement of nutrient-rich waters pushed closer to shore by periodic meridional winds (occurring about every 12 – 14 years) may be responsible for bringing marine mammals closer to land, thus increasing the probability of stranding (Bradshaw et al. 2006). The papers conclude, however, that while an

overarching model can be helpful for providing insight into the prediction of strandings, the particular reasons for each one are likely to be quite varied.

6.4.2.1.4 Navigational Error

Geomagnetism: It has been hypothesized that, like some land animals, marine mammals may be able to orient to the Earth's magnetic field as a navigational cue, and that areas of local magnetic anomalies may influence strandings (Bauer et al. 1985; Klinowska, 1985; Kirschvink et al. 1986; Klinowska, 1986; Walker et al. 1992; Wartzok and Ketten, 1999). In a plot of live stranding positions in Great Britain with magnetic field maps, Klinowska (1985, 1986) observed an association between live stranding positions and magnetic field levels. In all cases, live strandings occurred at locations where magnetic minima, or lows in the magnetic fields, intersect the coastline. Kirschvink et al. (1986) plotted stranding locations on a map of magnetic data for the east coast of the US, and were able to develop associations between stranding sites and locations where magnetic minima intersected the coast. The authors concluded that there were highly significant tendencies for cetaceans to beach themselves near these magnetic minima and coastal intersections. The results supported the hypothesis that cetaceans may have a magnetic sensory system similar to other migratory animals, and that marine magnetic patterns may influence long-distance movements (Kirschvink et al. 1986). Walker et al. (1992) examined fin whale swim patterns off the northeastern US continental shelf, and reported that migrating animals aligned with lows in the gradient of magnetic intensity. While a similar pattern between magnetic features and marine mammal strandings at New Zealand stranding sites was not seen (Brabyn and Frew, 1994), mass strandings in Hawaii typically were found to occur within a narrow range of magnetic anomalies (Mazzuca et al. 1999).

Echolocation:Disruption in Shallow Water- Some researchers believe stranding may result from reductions in the effectiveness of echolocation within shallow water, especially with the pelagic species of odontocetes who may be less familiar with coastline (Dudok van Heel, 1966; Chambers and James, 2005). For an odontocete, echoes from echolocation signals contain important information on the location and identity of underwater objects and the shoreline. The authors postulate that the gradual slope of a beach may present difficulties to the navigational systems of some cetaceans, since it is common for live strandings to occur along beaches with shallow, sandy gradients (Brabyn and McLean, 1992; Mazzuca et al. 1999; Maldini et al. 2005; Walker et al. 2005). A contributing factor to echolocation interference in turbulent, shallow water is the presence of microbubbles from the interaction of wind, breaking waves, and currents. Additionally, ocean water near the shoreline can have an increased turbidity (e.g., floating sand or silt, particulate plant matter, etc.) due to the run-off of fresh water into the ocean, either from rainfall or from freshwater outflows (e.g., rivers and creeks). Collectively, these factors can reduce and scatter the sound energy within echolocation signals and reduce the perceptibility of returning echoes of interest.

Social cohesion: Many pelagic species such as sperm whales, pilot whales, melon-head whales, and false killer whales, and some dolphins occur in large groups with strong social bonds between individuals. When one or more animals strand due to any number of causative events, then the entire pod may follow suit out of social cohesion (Geraci et al. 1999; Conner, 2000; Perrin and Geraci, 2002; NMFS, 2007).

Predation: Many species of marine mammal serve as prey to other animals and forms of marine life, including sharks and even other marine mammals. Predation from sharks is considered to be

a contributing factor in the decline of the Hawaiian monk seal (Geraci et al. 1999). A stranded marine mammal will sometimes show signs of interactions with predators such as bites, teeth marks, and other injuries, which occasionally are severe enough to have been the primary cause of injury, death, and stranding.

6.4.2.2 Human Influenced (Anthropogenic) Causes

Over the past few decades there has been an increase in marine mammal mortalities believed to be caused by a variety of human activities (Geraci et al. 1999; NMFS 2000b), such as gunshots, ship strikes (Nelson et al. 2007), and other trauma and mutilations.

- Gunshot injuries are the most common man-made cause of strandings in sea lions and seals on the U.S. West Coast (NMFS 2007b).

- Every year a few northern right whales are killed within shipping lanes along the U.S. Atlantic coast, which may be enough to jeopardize stock recovery (Geraci et al. 1999).

- In 1998, two bottlenose dolphins and a calf were killed by vessel strikes in the Gulf of Mexico (NMFS 2005f).

- In 1999 there was one report of a stranded false killer whale on the Alabama coast that was classified as likely caused by fishery interactions or other human interaction due to limb mutilation (the fins and flukes of the animal had been amputated) (NMFS 2005c).

- 1,377 bottlenose dolphins were found stranded in the Gulf of Mexico from 1999 through 2003; 73 animals (11 percent) showed evidence of human interactions as the cause of death (e.g., gear entanglement, mutilations, gunshot wounds) (NMFS 2005f).

Data from strandings in which there was evidence of human interaction is available for the years 1999–2000. Table 6-5 provides the number of stranded marine mammals (cetaceans and pinnipeds) during this period that displayed evidence of human interactions (taken from NMFS 2007f). (Stranding data for the California region for the year 1999 is unavailable; therefore numbers are for stranded animals in 2000 only. Similarly, data is unavailable for the year 2000 in the Alaska region; numbers provided represent strandings for 1999 only.)

Table 6-5. Summary of Marine Mammal Strandings by Cause for Each Region from 1999-2000

Interaction	Southeast	Northeast	Northwest	California	Alaska
Fisheries	89	75	10	30	16
Vessel Strike	9	6	1	8	2
Gun Shot	6	6	12	41	4
Blunt Trauma	-	1	-	-	-
Mutilation	4	17	-	-	-
Plastic Ingestion	1	3	-	-	-
Power Plant Entrapment	1	11	-	23	-
Harassment	-	9	-	-	-
Arrow Wound	-	-	1	-	-
Harpoon Wound	-	-	2	-	-
Hit by Car	-	-	1	1	-
Hit by Train	-	-	1	-	-
Marine Debris Entanglement	-	-	1	3	-
Total	**110**	**128**	**27**	**106**	**22**

Source: National Marine Fisheries Service, 2000b

6.4.2.2.1 Fisheries Interaction: By-Catch and Entanglement

The incidental catch of marine mammals in commercial fisheries is a significant threat to the survival and recovery of many populations of marine mammals (Geraci et al. 1999; Baird, 2002; Culik, 2002; Carretta et al. 2004; Geraci and Lounsbury, 2005; NMFS, 2007). Interactions with fisheries and entanglement in discarded or lost gear continue to be a major factor in their deaths worldwide (Geraci et al. 1999; Nieri et al. 1999; Geraci and Lounsbury, 2005; Read et al. 2006; Zeeber et al. 2006). For instance, baleen whales and pinnipeds have been found entangled in nets, ropes, monofilament line, and other fishing gear that has been discarded out at sea (Geraci et al. 1999; Campagna et al. 2007).

Bycatch- By-catch is the catching of non-target species within a given fishing operation and can include invertebrates, fish, sea turtles, birds, and marine mammals (NRC, 2006). Read et al. (2006) estimated the magnitude of marine mammal by-catch in US and global fisheries. Data for the United States was obtained from fisheries observer programs, reports of entangled stranded animals, and fishery logbooks. In US fisheries, the mean annual by-catch of marine mammals between 1990 and 1999 was 6,215 animals (SE=+/-448). Eighty-four percent of cetacean by-catch occurred in gill-net fisheries, with dolphins and porpoises constituting the majority of these. The authors noted a 40 percent decline in marine mammal by-catch in the years 1995-1999 compared to 1990-1994, and suggested that effective conservation measures implemented during the later time period played a significant role.

To estimate annual global by-catch, Read et al. (2006) used US vessel by-catch data from 1990-1994 and extrapolated to the world's vessels for the same time period. They calculated an estimate of 653,365 marine mammals caught annually around the world, again with most occurring in gill-net fisheries. The authors concluded that with global marine mammal by-catch likely to be in the hundreds of thousands every year, by-catch in fisheries will be the single greatest threat to many marine mammal populations around the world.

Entanglement- Entanglement in fishing gear is a major cause of death or severe injury among the whales in the action area. Entangled marine mammals may die as a result of drowning, escape with pieces of gear still attached to their bodies, or manage to be set free either of their own accord or by fishermen. Many large whales carry off gear after becoming entangled (Read et al. 2006). Many times when a marine mammal swims off with gear attached, the end result can be fatal. The gear may be become too cumbersome for the animal, or it can be wrapped around a crucial body part and tighten over time. Stranded marine mammals frequently exhibit signs of previous fishery interaction, such as scarring or gear attached to their bodies, and the cause of death for many stranded marine mammals is often attributed to such interactions (Baird and Gorgone, 2005). Marine mammals that die or are injured in fisheries may not wash ashore and not all animals that do wash ashore exhibit clear signs of interactions, stranding data probably underestimate fishery-related mortality and serious injury (NMFS 2005a)

From 1993 through 2003, 927 harbor porpoises were reported stranded from Maine to North Carolina, many of which had cuts and body damage suggestive of net entanglement (NMFS 2005e). In 1999 it was possible to determine that the cause of death for 38 of the stranded porpoises was from fishery interactions, with one additional animal having been mutilated (right flipper and fluke cut off) (NMFS 2005e). In 2000, one stranded porpoise was found with monofilament line wrapped around its body (NMFS 2005e). In addition, in 2003, nine stranded harbor porpoises were attributed to fishery interactions, with an additional three mutilated animals (NMFS 2005e). An estimated 78 baleen whales were killed annually in the offshore southern California/Oregon drift gillnet fishery during the 1980s (Heyning and Lewis 1990). From 1998-2005, based on observer records, five fin whales (CA/OR/WA stock), 19 humpback whales (ENP stock), and six sperm whales (CA/OR/WA stock) were either seriously injured or killed in fisheries off the mainland west coast of the U.S. (California Marine Mammal Stranding Network Database 2006).

6.4.2.2.2 Ship Strike

Ship strikes to marine mammals are another cause of mortality and stranding (Laist et al., 2001; Geraci and Lounsbury 2005; de Stephanis and Urquiola 2006). An animal at the surface could be struck directly by a vessel, a surfacing animal could hit the bottom of a vessel, or an animal just below the surface could be cut by a vessel's propeller. The severity of injuries typically depends on the size and speed of the vessel (Knowlton and Kraus 2001; Laist et al. 2001; Vanderlaan and Taggart 2007).

An examination of all known ship strikes from all shipping sources (civilian and military) indicates vessel speed is a principal factor in whether a vessel strike results in death (Knowlton and Kraus 2001; Laist et al. 2001, Jensen and Silber 2003; Vanderlaan and Taggart 2007). In assessing records in which vessel speed was known, Laist et al. (2001) found a direct relationship between the occurrence of a whale strike and the speed of the vessel involved in the collision. The authors concluded that most deaths occurred when a vessel was traveling in excess of 13 knots.

Jensen and Silber (2003) detailed 292 records of known or probable ship strikes of all large whale species from 1975 to 2002. Of these, vessel speed at the time of collision was reported for 58 cases. Of these cases, 39 (or 67%) resulted in serious injury or death (19 or 33% resulted in serious injury as determined by blood in the water, propeller gashes or severed tailstock, and fractured skull, jaw, vertebrae, hemorrhaging, massive bruising or other injuries noted during

necropsy and 20 or 35% resulted in death). Operating speeds of vessels that struck various species of large whales ranged from 2 to 51 knots. The majority (79%) of these strikes occurred at speeds of 13 knots or greater. The average speed that resulted in serious injury or death was 18.6 knots. Pace and Silber (2005) found that the probability of death or serious injury increased rapidly with increasing vessel speed. Specifically, the predicted probability of serious injury or death increased from 45 percent to 75 % as vessel speed increased from 10 to 14 knots, and exceeded 90% at 17 knots. Higher speeds during collisions result in greater force of impact, but higher speeds also appear to increase the chance of severe injuries or death by pulling whales toward the vessel. Computer simulation modeling showed that hydrodynamic forces pulling whales toward the vessel hull increase with increasing speed (Clyne 1999, Knowlton et al. 1995).

The growth in civilian commercial ports and associated commercial vessel traffic is a result in the globalization of trade. The Final Report of the NOAA International Symposium on "Shipping Noise and Marine Mammals: A Forum for Science, Management, and Technology" stated that the worldwide commercial fleet has grown from approximately 30,000 vessels in 1950 to over 85,000 vessels in 1998 (NRC 2003; Southall 2005). Between 1950 and 1998, the U.S. flagged fleet declined from approximately 25,000 to less than 15,000 and currently represents only a small portion of the world fleet. From 1985 to 1999, world seaborne trade doubled to 5 billion tons and currently includes 90 percent of the total world trade, with container shipping movements representing the largest volume of seaborne trade. It is unknown how international shipping volumes and densities will continue to grow. However, current statistics support the prediction that the international shipping fleet will continue to grow at the current rate or at greater rates in the future. Shipping densities in specific areas and trends in routing and vessel design are as, or more, significant than the total number of vessels. Densities along existing coastal routes are expected to increase both domestically and internationally. New routes are also expected to develop as new ports are opened and existing ports are expanded. Vessel propulsion systems are also advancing toward faster ships operating in higher sea states for lower operating costs; and container ships are expected to become larger along certain routes (Southall 2005).

While there are reports and statistics of whales struck by vessels in U.S. waters, the magnitude of the risks of commercial ship traffic poses to marine mammal populations is difficult to quantify or estimate. In addition, there is limited information on vessel strike interactions between ships and marine mammals outside of U.S. waters (de Stephanis and Urquiola 2006). Laist et al. (2001) concluded that ship collisions may have a negligible effect on most marine mammal populations in general, except for regional based small populations where the significance of low numbers of collisions would be greater given smaller populations or populations segments.

Navy ship traffic is a small fraction of the overall U.S. commercial and fishing vessel traffic. While U.S. Navy vessel movements may contribute to the ship strike threat, given the lookout and mitigation measures adopted by the Navy, probability of vessel strikes is greatly reduced. Furthermore, actions to avoid close interaction of Navy ships and marine mammals and sea turtles, such as maneuvering to keep away from any observed marine mammal and sea turtle are part of existing at-sea protocols and standard operating procedures. Navy ships have up to three or more dedicated and trained lookouts as well as two to three bridge lookouts during at-sea movements who would be searching for any whales, sea turtles, or other obstacles on the water surface. Such lookouts are expected to further reduce the chances of a collision.

6.4.2.2.3 Ingestion of Plastic Objects and Other Marine Debris And Toxic Pollution Exposure

For many marine mammals, debris in the marine environment is a great hazard and can be harmful to wildlife. Not only is debris a hazard because of possible entanglement, animals may mistake plastics and other debris for food (NMFS 2007g). There are certain species of cetaceans, along with Florida manatees, that are more likely to eat trash, especially plastics, which is usually fatal for the animal (Geraci et al., 1999).

Between 1990 through October 1998, 215 pygmy sperm whales stranded along the U.S. Atlantic coast from New York through the Florida Keys (NMFS 2005a). Remains of plastic bags and other debris were found in the stomachs of 13 of these animals (NMFS 2005a). During the same time period, 46 dwarf sperm whale strandings occurred along the U.S. Atlantic coastline between Massachusetts and the Florida Keys (NMFS 2005d). In 1987 a pair of latex examination gloves was retrieved from the stomach of a stranded dwarf sperm whale (NMFS 2005d). 125 pygmy sperm whales were reported stranded from 1999 – 2003 between Maine and Puerto Rico; in one pygmy sperm whale found stranded in 2002, red plastic debris was found in the stomach along with squid beaks (NMFS 2005a).

Sperm whales have been known to ingest plastic debris, such as plastic bags (Evans et al. 2003; Whitehead 2003). While this has led to mortality, the scale to which this is affecting sperm whale populations is unknown, but Whitehead (2003) suspects it is not substantial at this time.

High concentrations of potentially toxic substances within marine mammals along with an increase in new diseases have been documented in recent years. Scientists have begun to consider the possibility of a link between pollutants and marine mammal mortality events. NMFS takes part in a marine mammal bio-monitoring program not only to help assess the health and contaminant loads of marine mammals, but also to assist in determining anthropogenic impacts on marine mammals, marine food chains and marine ecosystem health. Using strandings and bycatch animals, the program provides tissue/serum archiving, samples for analyses, disease monitoring and reporting, and additional response during disease investigations (NMFS 2007).

The impacts of these activities are difficult to measure. However, some researchers have correlated contaminant exposure to possible adverse health effects in marine mammals. Contaminants such as organochlorines do not tend to accumulate in significant amounts in invertebrates, but do accumulate in fish and fish-eating animals. Thus, contaminant levels in planktivorous mysticetes have been reported to be one to two orders of magnitude lower compared to piscivorous odontocetes (Borell 1993; O'Shea and Brownell 1994; O'Hara and Rice 1996; O'Hara et al. 1999).

The manmade chemical PCB (polychlorinated biphenyl), and the pesticide DDT (dichloro diphyenyl trichloroethane), are both considered persistent organic pollutants that are currently banned in the United States for their harmful effects in wildlife and humans (NMFS, 2007c). Despite having been banned for decades, the levels of these compounds are still high in marine mammal tissue samples taken along U.S. coasts (Hickie et al. 2007; Krahn et al. 2007; NMFS 2007c). Both compounds are long-lasting, reside in marine mammal fat tissues (especially in the blubber), and can be toxic causing effects such as reproductive impairment and immunosuppression (NMFS 2007c).

Both long-finned and short-finned pilot whales have a tendency to mass strand throughout their range. Short-finned pilot whales have been reported as stranded as far north as Rhode Island, and long-finned pilot whales as far south as South Carolina (NMFS 2005b). For U.S. east coast

stranding records, both species are lumped together and there is rarely a distinction between the two because of uncertainty in species identification (NMFS 2005b). Since 1980 within the Northeast region alone, between 2 and 120 pilot whales have stranded annually either individually or in groups (NMFS 2005b). Between 1999 and 2003 from Maine to Florida, 126 pilot whales were reported to be stranded, including a mass stranding of 11 animals in 2000 and another mass stranding of 57 animals in 2002, both along the Massachusetts coast (NMFS 2005b).

It is unclear how much of a role human activities play in these pilot whale strandings, and toxic poisoning may be a potential human-caused source of mortality for pilot whales (NMFS 2005b). Moderate levels of PCBs and chlorinated pesticides (such as DDT, DDE, and dieldrin) have been found in pilot whale blubber (NMFS 2005b). Bioaccumulation levels have been found to be more similar in whales from the same stranding event than from animals of the same age or sex (NMFS 2005b). Numerous studies have measured high levels of toxic metals (mercury, lead, and cadmium), selenium, and PCBs in pilot whales in the Faroe Islands (NMFS 2005b). Population effects resulting from such high contamination levels are currently unknown (NMFS 2005b).

Habitat contamination and degradation may also play a role in marine mammal mortality and strandings. Some events caused by man have direct and obvious effects on marine mammals, such as oil spills (Geraci et al. 1999). However, in most cases, effects of contamination will more than likely be indirect in nature, such as effects on prey species availability, or by increasing disease susceptibility (Geraci et al. 1999).

Navy ship transit between ports and exercise locations has the potential for release of small amounts of pollutant discharges into the water column. Navy ships are not a typical source, however, of either pathogens or other contaminants with bioaccumulation potential such as pesticides and PCBs. Furthermore, any vessel discharges such as bilgewater and deck runoff associated with the vessels would be in accordance with international and U.S. requirements for eliminating or minimizing discharges of oil, garbage, and other substances, and not likely to contribute significant changes to ocean water quality.

6.4.2.2.4 Anthropogenic Sound

Anthropogenic sound that could affect ambient sound arises from the following general types of activities in and near the sea, any combination of which, can contribute to the total sound at any one place and time. These sounds include: transportation; dredging; construction; oil, gas, and mineral exploration in offshore areas; geophysical seismic and/or mapping surveys; commercial and military sonar; explosions; and ocean research activities (Richardson et al. 1995a).

Mechanical noise from commercial fishing vessels, cruise ships, cargo transports, recreational boats, and aircraft, all contribute sound into the ocean (NRC 2003, 2006). Mechanical noise from Navy ships, especially those engaged in ASW, is very quiet in comparison to civilian vessels of similar or larger size. This general feature is also enhanced by the use of additional quieting technologies as a means of limiting passive detection by opposing submarines.

Several investigators have argued that anthropogenic sources of noise have increased ambient sound levels in the ocean over the last 50 years (NRC 1994, 2000, 2003, 2005; Richardson et al. 1995a; Jasny et al. 2005; McDonald et al. 2006). Much of this increase is due to increased shipping due to ships becoming more numerous and of larger tonnage (National Research Council, 2003; McDonald et al. 2006). Andrew et al. (2002) compared ocean ambient sound from the 1960s with the 1990s for a receiver off the California coast. The data showed an

increase in ambient noise of approximately 10 dB in the frequency range of 20 to 80 Hz and 200 and 300 Hz, and about 3 dB at 100 Hz over a 33-year period.

Urick (1983) provided a discussion of the ambient sound spectrum expected in the deep ocean. Shipping, seismic activity, and weather are the primary causes of deep-water ambient sound. The ambient sound frequency spectrum can be predicted fairly accurately for most deep-water areas based primarily on known shipping traffic density and wind state (wind speed, Beaufort wind force, or sea state) (Urick 1983). For example, for frequencies between 100 and 500 Hz, Urick (1983) estimated the average deep water ambient sound spectra to be 73 to 80 dB for areas of heavy shipping traffic and high sea states, and 46 to 58 dB for light shipping and calm seas. In contrast to deep water, ambient sound levels in shallow waters (i.e., coastal areas, bays, harbors, etc.) are subject to wide variations in level and frequency depending on time and location. The primary sources of sound include distant shipping and industrial activities, wind and waves, marine animals (Urick 1983). At any given time and place, the ambient sound is a mixture of all of these sound variables. In addition, sound propagation is also affected by the variable shallow water conditions, including the depth, bottom slope, and type of bottom. Where the bottom is reflective, the sounds levels tend to be higher than when the bottom is absorptive.

Most observations of behavioral responses of marine mammals to the sounds produced have been limited to short-term behavioral responses, which included the cessation of feeding, resting, or social interactions. Carretta et al. (2001) and Jasny et al. (2005) identified increasing levels of anthropogenic noise as a habitat concern for whales and other marine mammals because of its potential to affect their ability to communicate. Acoustic devices have also been used in fisheries nets to prevent marine mammal entanglement and to deter seals from salmon cages (Johnson and Woodley 1998), little is known about their effects on non-target species.

Noise from Aircraft and Vessel Movement

Surface shipping is the most widespread source of anthropogenic, low frequency (0 to 1,000 Hz) noise in the oceans and may contribute to over 75% of all human sound in the sea (Simmonds and Hutchinson 1996, International Council for the Exploration of the Sea [ICES] 2005b). The Navy estimated that the 60,000 vessels of the world's merchant fleet, annually emit low frequency sound into the world's oceans for the equivalent of 21.9 million days, assuming that 80 percent of the merchant ships are at sea at any one time (DoN 2001). Ross (1976) has estimated that between 1950 and 1975, shipping had caused a rise in ambient noise levels of 10 dB. He predicted that this would increase by another 5 dB by the beginning of the 21st century. The National Resource Council (1997) estimated that the background ocean sound level at 100 Hz has been increasing by about 1.5 dB per decade since the advent of propeller-driven ships. Michel et al. (2001) suggested an association between long-term exposure to low frequency sounds from shipping and an increased incidence of marine mammal mortalities caused by collisions with ships.

Airborne sound from a low-flying helicopter or airplane may be heard by marine mammals and turtles while at the surface or underwater. Responses by mammals and turtles could include hasty dives or turns, or decreased foraging (Soto et al. 2006). Whales may also slap the water with flukes or flippers, or swim away from low flying aircraft. Due to the transient nature of sounds from aircraft involved in at-sea training, such sounds would not likely cause physical effects.

Sound emitted from large vessels, particularly in the course of transit, is the principal source of sound in the ocean today, primarily due to the properties of sound emitted by civilian cargo

vessels (Richardson et al. 1995; Arveson and Vendittis 2000). Ship propulsion and electricity generation engines, engine gearing, compressors, bilge and ballast pumps, as well as hydrodynamic flow surrounding a ship's hull and any hull protrusions contribute to a large vessels' noise emission into the marine environment. Prop-driven vessels also generate noise through cavitation, which accounts much of the sound emitted by a large vessel depending on its travel speed. Military vessels underway or involved in naval training activities or exercises, also introduce anthropogenic sound into the marine environment. Noise emitted by large vessels can be characterized as low-frequency, continuous, and tonal. The sound pressure levels at the vessel will vary according to speed, burden, capacity and length (Richardson et al. 1995; Arveson and Vendittis 2000). Vessels ranging from 135 to 337 meters generate peak source sound levels from 169- 200 dB between 8 Hz and 430 Hz, although Arveson and Vendittis (2000) documented components of higher frequencies (10-30 kHz) as a function of newer merchant ship engines and faster transit speeds. As noted previously, Navy ships in general and in particular those engaged in ASW, are designed to be very quiet as a means of limiting passive detection by opposing submarines.

Whales have variable responses to vessel presence or approaches, ranging from apparent tolerance to diving away from a vessel. Unfortunately, it is not always possible to determine whether the whales are responding to the vessel itself or the noise generated by the engine and cavitation around the propeller. Apart from some disruption of behavior, an animal may be unable to hear other sounds in the environment due to masking by the noise from the vessel. Any masking of environmental sounds or conspecific sounds is expected to be temporary, as noise dissipates with a vessel transit through an area.

Vessel noise primarily raises concerns for masking of environmental and conspecific cues. However, exposure to vessel noise of sufficient intensity and/or duration can also result in temporary or permanent loss of sensitivity at a given frequency range, referred to as TTS or PTS. Threshold shifts are assumed to be possible in marine mammal species as a result of prolonged exposure to large vessel traffic noise due to its intensity, broad geographic range of effectiveness, and constancy.

Collectively, significant cumulative exposure to individuals, groups, or populations can occur if they exhibit site fidelity to a particular area; for example, whales that seasonally travel to a regular area to forage or breed may be more vulnerable to noise from large vessels compared to transiting whales. Any PTS in a marine animal's hearing capability, especially at particular frequencies for which it can normally hear best, can impair its ability to perceive threats, including ships.

Most observations of behavioral responses of marine mammals to human generated sounds have been limited to short-term behavioral responses, which included the cessation of feeding, resting, or social interactions. Nowacek et al. (2007) provide a detailed summary of cetacean response to underwater noise.

Given the sound propagation of low frequency sounds, a large vessel in this sound range can be heard 139-463 km away (Ross 1976 in Polefka 2004). Navy vessels, however, have incorporated significant underwater ship quieting technology to reduce their acoustic signature (as compared to a similarly-sized vessel) in order to reduce their vulnerability to detection by enemy passive acoustics (Southall 2005). Therefore, the potential for TTS or PTS from Navy vessel and aircraft movement is extremely low given that the exercises and training events are transitory in time,

with vessels moving over large area of the ocean. A marine mammal or sea turtle is unlikely to be exposed long enough at high levels for TTS or PTS to occur. Any masking of environmental sounds or conspecific sounds is expected to be temporary, as noise dissipates with a Navy vessel transiting through an area. If behavioral disruptions result from the presence of aircraft or vessels, it is expected to be temporary. Animals are expected to resume their migration, feeding, or other behaviors without any threat to their survival or reproduction. However, if an animal is aware of a vessel and dives or swims away, it may successfully avoid being struck.

Commercial and Research Sonar

Almost all vessels at sea are equipped with active sonar for use in measuring the depth of the water: a fathometer. In addition, many vessels engaged in commercial or recreational fishing also use active sonar commonly referred to as "fish-finders." Both types of sonar tend to be higher in frequency and lower in power as compared to the hull mounted MFA or HFA sonar used during Navy training; however, there are many more of these sonars, and they are in use much more often and in more locations than Navy sonars.

Seismic sound sources employed include powerful multibeam and sidescan sonars that are generally used for mapping the ocean floor and include both mid-frequency and high-frequency systems. During mapping surveys, these sonars are run continuously, sweeping the large areas of ocean to accurately chart the complex bathymetry present on the ocean floor.

Navy Sonar

Naval sonars are designed for three primary functions: submarine hunting, mine hunting, and shipping surveillance. There are two classes of sonars employed by the Navy: active sonars and passive sonars. Most active military sonars operate in a limited number of areas, and are most likely not a significant contributor to a comprehensive global ocean noise budget (ICES 2005b).

The effects of MFA/HFA naval sonar on marine wildlife have not been studied as extensively as the effects of air-guns used in seismic surveys (Madsen et al. 2006; Stone and Tasker 2006; Wilson et al. 2006; Palka and Johnson 2007; Parente et al. 2007). Maybaum (1989; 1993) observed changes in behavior of humpbacks during playback tapes of the M-1002 system (using 203 dB re 1 µPa-m for study); specifically, a decrease in respiration, submergence, and aerial behavior rates; and an increase in speed of travel and track linearity. Direct comparison of Maybaum's results, however, with Navy MFA sonar are difficult to make. Maybaum's signal source, the commercial M-1002, is not similar to how naval mid-frequency sonar operates. In addition, behavioral responses were observed during playbacks of a control tape, (i.e. a tape with no sound signal) so interpretation of Maybaum's results are inconclusive.

In the Caribbean, sperm whales were observed to interrupt their activities by stopping echolocation and leaving the area in the presence of underwater sounds surmised (since they did not observe any vessels) to have originated from submarines using sonar (Watkins and Schevill 1975; Watkins et al. 1985). The authors did not report receive levels from these exposures, and also got a similar reaction from artificial noise they generated by banging on their boat hull. It was unclear if the sperm whales were reacting to the sonar signal itself or to a potentially new unknown sound in general.

Research by Nowacek, et al. (2004) on North Atlantic right whales using a whale alerting signal designed to alert whales to human presence suggests that received sound levels of only 133 to 148 pressure level (decibel [dB] re 1 microPascals per meter [µPa-m]) for the duration of the

sound exposure may disrupt feeding behavior. The authors did note, however, that within minutes of cessation of the source, a return to normal behavior would be expected. Direct comparison of the Nowacek et al. (2004) sound source to MFA sonar, however, is not possible given the radically different nature of the two sources. Nowacek et al.'s source was a series of non-sonar like sounds designed to purposely alert the whale, lasting several minutes, and covering a broad frequency band. Direct differences between Nowacek et al. (2004) and MFA sonar is summarized below from Nowacek et al. (2004) and Nowacek et al. (2007):

(1) Signal duration: Time difference between the two signals is significant, 18-minute signal used by Nowacek et al. verses < 1-sec for MFA sonar.

(2) Frequency modulation: Nowacek et al. contained three distinct signals containing frequency modulated sounds:

> 1st - alternating 1-sec pure tone at 500 and 850 Hz

> 2nd - 2-sec logarithmic down-sweep from 4500 to 500 Hz

> 3rd - pair of low-high (1500 and 2000 Hz) sine wave tones amplitude modulated at 120 Hz

(3) Signal to noise ratio: Nowacek et al.'s signal maximized signal to noise ratio so that it would be distinct from ambient noise and resist masking.

(4) Signal acoustic characteristics: Nowacek et al.'s signal comprised of disharmonic signals spanning northern right whales' estimated hearing range.

Given these differences, therefore, the exact cause of apparent right whale behavior noted by the authors can not be attributed to any one component since the source was such a mix of signal types.

6.4.3 Stranding Event Case Studies

6.4.3.1 Beaked Whale Strandings

Over the past two decades, several mass stranding events involving beaked whales have been documented. While beaked whale strandings have occurred since the 1800s (Geraci and Lounsbury 1993; Cox et al. 2006; Podesta et al. 2006), several mass strandings since have been associated with naval training activities that may have included mid-frequency sonar (Simmonds and Lopez-Jurado 1991; Frantzis 1998; Jepson et al. 2003; Cox et al. 2006). As Cox et al. (2006) concludes, the state of science can not yet determine if a sound source such as mid-frequency sonar alone causes beaked whale strandings, or if other factors (acoustic, biological, or environmental) must co-occur in conjunction with a sound source.

A review of historical data (mostly anecdotal) maintained by the Marine Mammal Program in the National Museum of Natural History, Smithsonian Institution reports 49 beaked whale mass stranding events between 1838 and 1999. The largest beaked whale mass stranding occurred in the 1870s in New Zealand when 28 Gray's beaked whales (*Mesoplodon grayi*) stranded. Blainsville's beaked whale (*Mesoplodon densirostris*) strandings are rare, and records show that they were involved in one mass stranding in 1989 in the Canary Islands. Cuvier's beaked whales (*Ziphius cavirostris*) are the most frequently reported beaked whale to strand, with at least 19 stranding events from 1804 through 2000 (DoC and DoN, 2001; Smithsonian Institution, 2000). While beaked whale strandings have occurred since the 1800s (Geraci and Lounsbury, 1993; Cox et al. 2006; Podesta et al. 2006), several mass strandings have been temporally and spatially associated with naval activities utilizing mid-frequency active (MFA) sonar (Simmonds and Lopez-Jurado, 1991; Frantzis, 1998; Jepson et al. 2003; Cox et al. 2006).

In the following sections, specific stranding events that have been putatively linked to sonar activities are discussed. These events represent a relatively small number of animals over an 11 year period (40 animals) and are not representative of worldwide beaked whale strandings, i.e. most strandings are not linked to naval activity (ICES, 2005a; 2005b; Podesta et al. 2006). Four of the five events discussed involved beaked whales and occurred during NATO exercises or events where US Navy presence was limited (Greece, Portugal, Spain). One of the five events involved only US Navy ships (Bahamas). These events are given specific consideration in the case studies that follow.

Beaked whale stranding events associated with potential naval activities:

1996	May	Greece (NATO/US)
2000	March	Bahamas (US)
2000	May	Portugal, Madeira Islands (NATO/US)
2002	September	Spain, Canary Islands (NATO/US)
2006	January	Spain, Mediterranean Sea coast (NATO/US)

6.4.3.2 Beaked Whale Case Studies

1996 Greece Beaked Whale Mass Stranding (May 12 – 13)

Description

Twelve Cuvier's beaked whales (*Ziphius cavirostris*) stranded along a 38.2-kilometer strand of the coast of the Kyparissiakos Gulf on May 12 and 13, 1996 (Frantzis, 1998).

From May 11 through May 15, the NATO research vessel *Alliance* was conducting sonar tests with signals of 600 Hz and 3 kHz and root-mean-squared (rms) sound pressure levels (SPL) of 228 and 226 dB re: 1µPa, respectively (D'Amico and Verboom, 1998; D'Spain et al. 2006). The timing and the location of the testing encompassed the time and location of the whale strandings (Frantzis, 1998).

Findings

Partial necropsies of eight of the animals were performed, including external assessments and the sampling of stomach contents. No abnormalities attributable to acoustic exposure were observed, but the stomach contents indicated that the whales were feeding on cephalods soon before the stranding event. No unusual environmental events before or during the stranding event could be identified (Frantzis, 1998).

Conclusions

The timing and spatial characteristics of this stranding event were atypical of stranding in Cuvier's beaked whale, particularly in this region of the world. No natural phenomenon that might contribute to the stranding event coincided in time with the mass stranding. Because of the rarity of mass strandings in the Greek Ionian Sea, the probability that the sonar tests and stranding coincided in time and location, while being independent of each other, was estimated as being extremely low (Frantzis, 1998). However, because information for the necropsies was incomplete and inconclusive, the cause of the stranding cannot be precisely determined.

2000 Bahamas Marine Mammal Mass Stranding (March 15-16)

Description

Seventeen marine mammals comprised of Cuvier's beaked whales, Blainville's beaked whales (*Mesoplodon densirostris*), Minke whales (*Balaenoptera acutorostrata*), and one spotted dolphin (*Stenella frontalis*), stranded along the Northeast and Northwest Providence Channels of the Bahamas Islands on March 15-16, 2000 (Evans and England, 2001). The strandings occurred over a 36-hour period and coincided with US Navy use of MFA sonar within the channel. Navy ships were involved in tactical sonar exercises for approximately 16 hours on March 15. The ships, which operated the AN/SQS-53C and AN/SQS-56, moved through the channel while emitting sonar pings approximately every 24 seconds. The timing of pings was staggered between ships and average source levels of pings varied from a nominal 235 dB SPL (AN/SQS-53C) to 223 dB SPL (AN/SQS-56). The center frequency of pings was 3.3 kHz and 6.8 to 8.2 kHz, respectively.

Seven of the animals that stranded died, while ten animals were returned to the water alive. The animals known to have died included five Cuvier's beaked whales, one Blainville's beaked whale, and the single spotted dolphin. Six necropsies were performed and three of the six necropsied whales (one Cuvier's beaked whale, one Blainville's beaked whale, and the spotted dolphin) were fresh enough to permit identification of pathologies by computerized tomography (CT). Tissues from the remaining three animals were in a state of advanced decomposition at the time of inspection.

Findings

All five necropsied beaked whales were in good body condition and did not show any signs of external trauma or disease. In the two best preserved whale specimens, hemorrhage was associated with the brain and hearing structures. Specifically, subarachnoid hemorrhage within the temporal region of the brain and intracochlear hemorrhages were noted. Similar findings of bloody effusions around the ears of two other moderately decomposed whales were consistent with the same observations in the freshest animals. In addition, three of the whales had small hemorrhages in their acoustic fats, which are fat bodies used in sound production and reception (i.e., fats of the lower jaw and the melon). The best-preserved whale demonstrated acute hemorrhage within the kidney, inflammation of the lung and lymph nodes, and congestion and mild hemorrhage in multiple other organs.

Other findings were consistent with stresses and injuries associated with the stranding process. These consisted of external scrapes, pulmonary edema and congestion.

The spotted dolphin demonstrated poor body condition and evidence of a systemic debilitating disease. In addition, since the dolphin stranding site was isolated from the acoustic activities of Navy ships, it was determined that the dolphin stranding was unrelated to the presence of Navy active sonar.

Conclusions

The post-mortem analyses of stranded beaked whales led to the conclusion that the immediate cause of death resulted from overheating, cardiovascular collapse and stresses associated with being stranded on land. However, the presence of subarachnoid and intracochlear hemorrhages were believed to have occurred prior to stranding and were hypothesized as being related to an

acoustic event. Passive acoustic monitoring records demonstrated that no large scale acoustic activity besides the Navy sonar exercise occurred in the times surrounding the stranding event. The mechanism by which sonar could have caused the observed traumas or caused the animals to strand was undetermined. The spotted dolphin was in overall poor condition for examination, but showed indications of long-term disease. No analysis of baleen whales (minke whale) was conducted. Baleen whale stranding events have not been associated with either low-frequency or MFA sonar use (ICES 2005a, 2005b).

2000 Madeira Island, Portugal Beaked Whale Strandings (May 10 – 14)

Description

Three Cuvier's beaked whales stranded on two islands in the Madeira Archipelago, Portugal, from May 10 – 14, 2000 (Cox et al. 2006). A joint NATO amphibious training exercise, named "Linked Seas 2000," which involved participants from 17 countries, took place in Portugal during May 2 – 15, 2000. The timing and location of the exercises overlapped with that of the stranding incident.

Findings

Two of the three whales were necropsied. Two heads were taken to be examined. One head was intact and examined grossly and by CT; the other was only grossly examined because it was partially flensed and had been seared from an attempt to dispose of the whale by fire (Ketten, 2005).

No blunt trauma was observed in any of the whales. Consistent with prior CT scans of beaked whales stranded in the Bahamas 2000 incident, one whale demonstrated subarachnoid and peribullar hemorrhage and blood within one of the brain ventricles. Post-cranially, the freshest whale demonstrated renal congestion and hemorrhage, which was also consistent with findings in the freshest specimens in the Bahamas incident.

Conclusions

The pattern of injury to the brain and auditory system were similar to those observed in the Bahamas strandings, as were the kidney lesions and hemorrhage and congestion in the lungs (Ketten, 2005). The similarities in pathology and stranding patterns between these two events suggested a similar causative mechanism. Although the details about whether or how sonar was used during "Linked Seas 2000" is unknown, the presence of naval activity within the region at the time of the strandings suggested a possible relationship to Navy activity.

2002 Canary Islands Beaked Whale Mass Stranding (24 September)

Description

On September 24, 2002, 14 beaked whales stranded on Fuerteventura and Lanzaote Islands in the Canary Islands (Jepson et al. 2003). Seven of the 14 whales died on the beach and the 7 were returned to the ocean. Four beaked whales were found stranded dead over the next three days either on the coast or floating offshore (Fernández et al. 2005). At the time of the strandings, an international naval exercise (Neo-Tapon 2002) that involved numerous surface warships and several submarines was being conducted off the coast of the Canary Islands. Tactical MFA sonar was utilized during the exercises, and strandings began within hours of the onset of the use of MFA sonar (Fernández et al. 2005).

Findings

Eight Cuvier's beaked whales, one Blainville's beaked whale, and one Gervais' beaked whale were necropsied; six of them within 12 hours of stranding (Fernández et al. 2005). The stomachs of the whales contained fresh and undigested prey contents. No pathogenic bacteria were isolated from the whales, although parasites were found in the kidneys of all of the animals. The head and neck lymph nodes were congested and hemorrhages were noted in multiple tissues and organs, including the kidney, brain, ears, and jaws. Widespread fat emboli were found throughout the carcasses, but no evidence of blunt trauma was observed in the whales. In addition, the parenchyma of several organs contained macroscopic intravascular bubbles and lesions, putatively associated with nitrogen off-gassing.

Conclusions

The association of NATO MFA sonar use close in space and time to the beaked whale strandings, and the similarity between this stranding event and previous beaked whale mass strandings coincident with sonar use, suggests that a similar scenario and causative mechanism of stranding may be shared between the events. Beaked whales stranded in this event demonstrated brain and auditory system injuries, hemorrhages, and congestion in multiple organs, similar to the pathological findings of the Bahamas and Madeira stranding events. In addition, the necropsy results of Canary Islands stranding event led to the hypothesis that the presence of disseminated and widespread gas bubbles and fat emboli were indicative of nitrogen bubble formation, similar to what might be expected in decompression sickness (Jepson et al. 2003; Fernández et al. 2005). Whereas gas emboli would develop from the nitrogen gas, fat emboli would enter the blood stream from ruptured fat cells (presumably where nitrogen bubble formation occurs) or through the coalescence of lipid bodies within the blood stream.

The possibility that the gas and fat emboli found by Fernández et al. (2005) was due to nitrogen bubble formation has been hypothesized to be related to either direct activation of the bubble by sonar signals or to a behavioral response in which the beaked whales flee to the surface following sonar exposure. The first hypothesis is related to rectified diffusion (Crum and Mao, 1996), the process of increasing the size of a bubble by exposing it to a sound field. This process is facilitated if the environment in which the ensonified bubbles exist is supersaturated with gas. Repetitive diving by marine mammals can cause the blood and some tissues to accumulate gas to a greater degree than is supported by the surrounding environmental pressure (Ridgway and Howard, 1979). Deeper and longer dives of some marine mammals, such as those conducted by beaked whales, are theoretically predicted to induce greater levels of supersaturation (Houser et al. 2001). If rectified diffusion were possible in marine mammals exposed to high-level sound, conditions of tissue supersaturation could theoretically speed the rate and increase the size of bubble growth. Subsequent effects due to tissue trauma and emboli would presumably mirror those observed in humans suffering from decompression sickness.

It is unlikely that the short duration of sonar pings would be long enough to drive bubble growth to any substantial size, if such a phenomenon occurs. However, an alternative but related hypothesis has also been suggested: stable bubbles could be destabilized by high-level sound exposures such that bubble growth then occurs through static diffusion of gas out of the tissues. In such a scenario the marine mammal would need to be in a gas-supersaturated state for a long enough period of time for bubbles to become of a problematic size. The second hypothesis speculates that rapid ascent to the surface following exposure to a startling sound might produce

tissue gas saturation sufficient for the evolution of nitrogen bubbles (Jepson et al. 2003; Fernández et al. 2005). In this scenario, the rate of ascent would need to be sufficiently rapid to compromise behavioral or physiological protections against nitrogen bubble formation.

Although theoretical predictions suggest the possibility for acoustically mediated bubble growth, there is considerable disagreement among scientists as to its likelihood (Piantadosi and Thalmann, 2004). Sound exposure levels predicted to cause *in vivo* bubble formation within diving cetaceans have not been evaluated and are suspected as needing to be very high (Evans, 2002; Crum et al. 2005). Further, although it has been argued that traumas from recent beaked whale strandings are consistent with gas emboli and bubble-induced tissue separations (Jepson et al. 2003), there is no conclusive evidence supporting this hypothesis and there is concern that at least some of the pathological findings (e.g., bubble emboli) are artifacts of the necropsy. Currently, stranding networks in the United States have agreed to adopt a set of necropsy guidelines to determine, in part, the possibility and frequency with which bubble emboli can be introduced into marine mammals during necropsy procedures (Arruda et al. 2007).

2006 Spain, Gulf of Vera Beaked Whale Mass Stranding (26-27 January)

Description

The Spanish Cetacean Society reported an atypical mass stranding of four beaked whales that occurred January 26, 2006, on the southeast coast of Spain near Mojacar (Gulf of Vera) in the Western Mediterranean Sea. According to the report, two of the whales were discovered the evening of January 26 and were found to be still alive. Two other whales were discovered during the day on January 27, but had already died. A following report stated that the first three animals were located near the town of Mojacar and were examined by a team from the University of Las Palmas de Gran Canarias, with the help of the stranding network of Ecologistas en Acción Almería-PROMAR and others from the Spanish Cetacean Society. The fourth animal was found dead on the afternoon of May 27, a few kilometers north of the first three animals.

From January 25-26, 2006, a NATO surface ship group (seven ships including one US ship under NATO operational command) conducted active sonar training against a Spanish submarine within 50 nm (93 km) of the stranding site.

Findings

Veterinary pathologists necropsied the two male and two female beaked whales (*Z. cavirostris*).

Conclusions

According to the pathologists, a likely cause of this type of beaked whale mass stranding event may have been anthropogenic acoustic activities. However, no detailed pathological results confirming this supposition have been published to date, and no positive acoustic link was established as a direct cause of the stranding.

Even though no causal link can be made between the stranding event and naval exercises, certain conditions may have existed in the exercise area that, in their aggregate, may have contributed to the marine mammal strandings (Freitas, 2004):

- Activities were conducted in areas of at least 1000 meters in depth near a shoreline where there is a rapid change in bathymetry on the order of 1000 – 6000 meters occurring a cross a relatively short horizontal distance (Freitas, 2004).

- Multiple ships--in this instance, five MFA sonar equipped vessels-- were operating in close proximity, in the same area, and over extended periods of time (20 hours). Whether the ships were operating MFA sonar, at what times, and in what capacity is unknown.

- Exercises took place in an area surrounded by landmasses, or in an embayment. Activities involving multiple ships employing MFA sonar near land may produce sound directed towards a channel or embayment that may cut off the lines of egress for marine mammals (Freitas, 2004).

Other Global Stranding Discussions

In the following sections, stranding events that have been putatively linked to US Navy activity in the popular press are presented. As detailed in the individual case study conclusions, the US Navy believes that there is sufficient evidence to refute allegations of impacts from MFA sonar.

2003 Washington State Harbor Porpoise Strandings (May 2 – June 2)

Description

At 1040 hours on May 5, 2003, the USS SHOUP began the use of MFA sonar as part of a naval exercise. At 1420, the USS SHOUP entered the Haro Strait and terminated active sonar use at 1438, thus limiting active sonar use within the strait to less than 20 minutes. Between May 2 and June 2, 2003, approximately 16 strandings involving 15 harbor porpoises (*Phocoena phocoena*) and one Dall's porpoise (*Phocoenoides dalli*) were reported to the Northwest Marine Mammal Stranding Network. A comprehensive review of all strandings and the events involving USS SHOUP on 5 May 2003 were presented in US Department of Navy (2004). Given that the USS SHOUP was known to have operated sonar in the strait on May 5, and that supposed behavioral reactions of killer whales (*Orcinus orca*) had been putatively linked to these sonar activities (NMFS Office of Protected Resources, 2005), the NMFS undertook an analysis of whether sonar caused the strandings of the harbor porpoises.

Whole carcasses of ten of harbor porpoises and the head of an additional porpoise were collected for analysis. Necropsies were performed on ten of the harbor porpoises and six whole carcasses and two heads were selected for CT imaging. Gross examination, histopathology, age determination, blubber analysis, and various other analyses were conducted on each of the carcasses (Norman et al. 2004).

Findings

Post-mortem findings and analysis details are found in Norman *et al*. (2004). All of the carcasses suffered from some degree of freeze-thaw artifact that hampered gross and histological evaluations. At the time of necropsy, three of the porpoises were moderately fresh, whereas the remainder of the carcasses was considered to have moderate to advanced decomposition. None of the 11 harbor porpoises demonstrated signs of acoustic trauma. In contrast, a putative cause of death was determined for 5 of the porpoises; 2 animals had blunt trauma injuries and 3 animals had indication of disease processes (fibrous peritonitis, salmonellosis, and necrotizing pneumonia). A cause of death could not be determined in the remaining animals, which is consistent with expected percentage of marine mammal necropsies conducted within the northwest region.

Conclusions

The NMFS concluded from a retrospective analysis of stranding events that the number of harbor porpoise stranding events in the approximate month surrounding the USS SHOUP use of sonar was higher than expected based on annual strandings of harbor porpoises (Norman et al. 2004). It is important to note that the number of strandings in the May-June timeframe in 2003 was also higher for the outer coast, indicating a much wider phenemona than use of sonar by USS SHOUP in Puget Sound for one day in May. The conclusion by NMFS that the number of strandings in 2003 was higher is also different from that of The Whale Museum, which has documented and responded to harbor porpoise strandings since 1980 (Osborne, 2003). According to The Whale Museum, the number of strandings as of May 15, 2003 was consistent with what was expected based on historical stranding records, and was less than that occurring in certain years. For example, since 1992 the San Juan Stranding Network has documented an average of 5.8 porpoise strandings per year. In 1997 there were 12 strandings in the San Juan Islands with more than 30 strandings throughout the general Puget Sound area. Disregarding the discrepancy in the historical rate of porpoise strandings and its relation to the USS SHOUP, NMFS acknowledged that the intense level of media attention focused on the strandings likely resulted in an increased reporting effort by the public over that which is normally observed (Norman et al. 2004). NMFS also noted in its report that the "sample size is too small and biased to infer a specific relationship with respect to sonar usage and subsequent strandings."

Seven of the porpoises collected and analyzed died prior to SHOUP departing to sea on May 5, 2003. Of these seven, one, discovered on May 5, 2003, was in a state of moderate decomposition, indicating it died before May 5; the cause of death was determined to be due, most likely, to salmonella septicemia. Another porpoise, discovered at Port Angeles on May 6, 2003, was in a state of moderate decomposition, indicating that this porpoise also died prior to May 5. One stranded harbor porpoise discovered fresh on May 6 is the only animal that could potentially be linked in time to the USS SHOUP's May 5th MFA sonar use. Necropsy results for this porpoise found no evidence of acoustic trauma. The remaining eight strandings were discovered one to three weeks after the USS SHOUP's May 5 transit of the Haro Strait, making it difficult to causally link the sonar activities of the USS SHOUP to the timing of the strandings. Two of the eight porpoises died from blunt trauma injury and a third suffered from parasitic infestation, which possibly contributed to its death (Norman et al. 2004). For the remaining five porpoises, NMFS was unable to identify the causes of death.

The speculative association of the harbor porpoise strandings to the use of sonar by the USS SHOUP is inconsistent with prior stranding events linked to the use of MFA sonar. Specifically, in prior events, the stranding of whales occurred over a short period of time (less than 36 hours), stranded individuals were spatially colocated, traumas in stranded animals were consistent between events, and active sonar was known or suspected to be in use. Although MFA sonar was used by the USS SHOUP, the distribution of harbor porpoise strandings by location and with respect to time surrounding the event do not support the suggestion that MFA sonar was a cause of harbor porpoise strandings. Rather, a complete lack of evidence of any acoustic trauma within the harbor porpoises, and the identification of probable causes of stranding or death in several animals, supports the conclusion that harbor porpoise strandings were unrelated to the sonar activities of the USS SHOUP.

2004 Hawai'i Melon-Headed Whale Mass Stranding (July 3-4)

Description

The majority of the following information is taken from the NMFS report on the stranding event (Southall et al. 2006). On the morning of July 3, 2004, between 150-200 melon-headed whales (*Peponocephala electra*) entered Hanalei Bay, Kauai. Individuals attending a canoe blessing ceremony observed the animals entering the bay at approximately 7:00 a.m. At 6:45 a.m. on July 3, 2004, approximately 25 nm (46 km) north of Hanalei Bay, active sonar was tested briefly prior to the start of an antisubmarine warfare (ASW) exercise.

The whales stopped in the southwest portion of the bay, grouping tightly, and displayed spy-hopping and tail-slapping behavior. As people went into the water among the whales, the pod separated into as many as four groups, with individual animals moving among the clusters. This continued through most of the day, with the animals slowly moving south and then southeast within the bay. By about 3 p.m., police arrived and kept people from interacting with the animals. At 4:45 p.m. on July 3, 2004, the RIMPAC Battle Watch Captain received a call from a National Marine Fisheries representative in Honolulu, Hawaii, reporting the sighting of as many as 200 melon-headed whales in Hanalei Bay. At 4:47 p.m. the Battle Watch Captain directed all ships in the area to cease active sonar transmissions.

At 7:20 p.m. on July 3, 2004, the whales were observed in a tight single pod 75 yards from the southeast side of the bay. The pod was circling in a group and displayed frequent tail slapping and whistle vocalizations and some spy hopping. No predators were observed in the bay and no animals were reported as having fresh injuries. The pod stayed in the bay through the night of July 3, 2004.

On the morning of July 4, 2004, the whales were observed to still be in the bay and collected in a tight group. A decision was made at that time to attempt to herd the animals out of the bay. A 700-to-800-foot rope was constructed by weaving together beach morning glory vines. This vine rope was tied between two canoes and with the assistance of 30 to 40 kayaks, was used to herd the animals out of the bay. By approximately 11:30 a.m. on July 4, 2004, the pod was coaxed out of the bay.

A single neonate melon-headed whale was observed in the bay on the afternoon of July 4, after the whale pod had left the bay. The following morning on July 5, 2004, the neonate was found stranded on Lumahai Beach. It was pushed back into the water but was found stranded dead between 9 and 10 a.m. near the Hanalei pier. NMFS collected the carcass and had it shipped to California for necropsy, tissue collection, and diagnostic imaging.

Following the stranding event, NMFS undertook an investigation of possible causative factors of the stranding. This analysis included available information on environmental factors, biological factors, and an analysis of the potential for sonar involvement. The latter analysis included vessels that utilized MFA sonar on the afternoon and evening of July 2. These vessels were to the southeast of Kauai, on the opposite side of the island from Hanalei Bay.

Findings

NMFS concluded from the acoustic analysis that the melon-headed whales would have had to have been on the southeast side of Kauai on July 2 to have been exposed to sonar from naval vessels on that day (Southall et al. 2006). There was no indication whether the animals were in that region or whether they were elsewhere on July 2. NMFS concluded that the animals would

have had to swim from 1.4-4.0 m/s for 6.5 to 17.5 hours after sonar transmissions ceased in order to reach Hanalei Bay by 7:00 a.m. on July 3. Sound transmissions by ships to the north of Hanalei Bay on July 3 were produced as part of exercises between 6:45 a.m. and 4:47 p.m. Propagation analysis conducted by the 3rd Fleet estimated that the level of sound from these transmissions at the mouth of Hanalei Bay could have ranged from 138-149 dB re: 1 μPa.

NMFS was unable to determine any environmental factors (e.g., harmful algal blooms, weather conditions) that may have contributed to the stranding. However, additional analysis by investigators found that a full moon occurred the evening before the stranding and was coupled with a squid run (Mobley et al. 2007). In addition, a group of 500-700 melon-headed whales were observed to come close to shore and interact with humans in Sasanhaya Bay, Rota, on the same morning as the whales entered Hanalei Bay (Jefferson et al. 2006). Previous records further indicated that, though the entrance of melon-headed whales into the shallows is rare, it is not unprecedented. A pod of melon-headed whales entered Hilo Bay in the 1870s in a manner similar to that which occurred at Hanalei Bay in 2004.

The necropsy of the melon-headed whale calf suggested that the animal died from a lack of nutrition, likely following separation from its mother. The calf was estimated to be approximately one week old. Although the calf appeared not to have eaten for some time, it was not possible to determine whether the calf had ever nursed after it was born. The calf showed no signs of blunt trauma or viral disease and had no indications of acoustic injury.

Conclusions

Although it is not impossible, it is unlikely that the sound level from the sonar caused the melon-headed whales to enter Hanalei Bay. This conclusion is based on a number of factors:

1. The speculation that the whales may have been exposed to sonar the day before and then fled to Hanalei Bay is not supported by reasonable expectation of animal behavior and swim speeds. The flight response of the animals would have had to persist for many hours following the cessation of sonar transmissions. Such responses have not been observed in marine mammals and no documentation of such persistent flight response after the cessation of a frightening stimulus has been observed in other mammals. The swim speeds, though feasible for the species, are highly unlikely to be maintained for the durations proposed, particularly since the pod was a mixed group containing both adults and neonates. Whereas adults may maintain a swim speed of 4.0 m/s for some time, it is improbable that a neonate could achieve the same for a period of many hours.

2. The area between the islands of Oahu and Kauai and the Pacific Missile Range Facility (PMRF) have been used in Rim of the Pacific (RIMPAC) exercises for more than 20 years, and are used year-round for ASW training using MFA sonar. Melon-headed whales inhabiting the waters around Kauai are likely not naive to the sound of sonar and there has never been another stranding event associated in time with ASW training at Kauai or in the Hawaiian Islands. Similarly, the waters surrounding Hawaii contain an abundance of marine mammals, many of which would have been exposed to the same sonar activities that were speculated to have affected the melon-headed whales. No other strandings were reported coincident with the RIMPAC exercises. This leaves it uncertain as to why melon-headed whales, and no other species of marine mammal, would respond to the sonar exposure by stranding.

3. At the nominal swim speed for melon-headed whales, the whales had to be within 1.5 to 2 nm (3 to 4 km) of Hanalei Bay before sonar was activated on July 3. The whales were not in their open ocean habitat but had to be close to shore at 6:45 a.m. when the sonar was activated to have been observed inside Hanalei Bay from the beach by 7:00 a.m. (Hanalei Bay is a very large area). This observation suggests that other potential factors could be causative of the stranding event (*see below*).

4. The simultaneous movement of 500-700 melon-headed whales and Risso's dolphins into Sasanhaya Bay, Rota, in the Northern Marianas Islands on the same morning as the 2004 Hanalei stranding (Jefferson et al. 2006) suggests that there may be a common factor which prompted the melon-headed whales to approach the shoreline. A full moon occurred the evening before the stranding and a run of squid was reported concomitant with the lunar activity (Mobley et al. 2007). Thus, it is possible that the melon-headed whales were capitalizing on a lunar event that provided an opportunity for relatively easy prey capture. A report of a pod entering Hilo Bay in the 1870s indicates that on at least one other occasion, melon-headed whales entered a bay in a manner similar to the occurrence at Hanalei Bay in July 2004. Thus, although melon-headed whales entering shallow embayments may be an infrequent event, and every such event might be considered anomalous, there is precedent for the occurrence.

5. The received noise sound levels at the bay were estimated to range from roughly 95 – 149 dB re: 1 µPa. Received levels as a function of time of day have not been reported, so it is not possible to determine when the presumed highest levels would have occurred and for how long. However, received levels in the upper range would have been audible by human participants in the bay. The statement by one interviewee that he heard "pings" that lasted an hour and that they were loud enough to hurt his ears is unreliable. Received levels necessary to cause pain over the duration stated would have been observed by most individuals in the water with the animals. No other such reports were obtained from people interacting with the animals in the water.

Although NMFS concluded that sonar use was a "plausible, if not likely, contributing factor in what may have been a confluence of events (Southall et al. 2006)," this conclusion was based primarily on the basis that there was an absence of any other compelling explanation. The authors of the NMFS report on the incident were unaware, at the time of publication, of the simultaneous event in Rota. In light of the simultaneous Rota event, the Hanalei stranding does not appear as anomalous as initially presented and the speculation that sonar was a causative factor is weakened. The Hanalei Bay incident does not share the characteristics observed with other mass strandings of whales coincident with sonar activity (e.g., specific traumas, species composition, etc.). In addition, the inability to conclusively link or exclude the impact of other environmental factors makes a causal link between sonar and the melon-headed whale strandings highly speculative at best.

1980- 2004 Beaked Whale Strandings in Japan (Brownell et al. 2004)

Description

Brownell et al. (2004) compare the historical occurrence of beaked whale strandings in Japan (where there are US Naval bases), with strandings in New Zealand (which lacks a US Naval base) and concluded the higher number of strandings in Japan may be related to the presence of the US Navy vessels using MFA sonar. While the dates for the strandings were well documented, the authors of the study did not attempt to correlate the dates of any navy activities or exercises with the dates of the strandings.

To fully investigate the allegation made by Brownell et al. (2004), the Center for Naval Analysis (CNA) looked at the past US Naval exercise schedules from 1980 to 2004 for the water around Japan in comparison to the dates for the strandings provided by Brownell et al. (2004). None of the strandings occurred during or soon (within weeks) after any US Navy exercises. While the CNA analysis began by investigating the probabilistic nature of any co-occurrences, the results were a 100% probability the strandings and sonar use were not correlated by time. Given there was no instance of co-occurrence in over 20 years of stranding data, it can be reasonably postulated that sonar use in Japan waters by US Navy vessels did not lead to any of the strandings documented by Brownell et al. (2004).

2004 Alaska Beaked Whale Strandings (June 17-19)

Description

In the timeframe between 17 June and 19 July 2004, five beaked whales were discovered at various locations along 1,600 miles of the Alaskan coastline and one was found floating (dead) at sea. Because the Navy exercise Alaska Shield/Northern Edge 2004 occurred within the approximate timeframe of these strandings, it has been alleged that sonar may have been the probable cause of the strandings. The Alaska Shield/Northern Edge 2004 exercise consisted of a vessel tracking event followed by a vessel boarding search and seizure event. There was no ASW component to the exercise, no use of MFA sonar, and no use of explosives in the water. There were no events in the Alaska Shield/Northern Edge exercise that could have caused any of the strandings over this 33 day period covering 1,600 miles of coastline.

2005 North Carolina Marine Mammal Mass Stranding Event (January 15-16)

Description

On January 15 and 16, 2005, 36 marine mammals consisting of 33 short-finned pilot whales, 1 minke whale, and 2 dwarf sperm whales stranded alive on the beaches of North Carolina (Hohn et al. 2006a). The animals were scattered across a 111-km area from Cape Hatteras northward. Because of the live stranding of multiple species, the event was classified as a UME. It is the only stranding on record for the region in which multiple offshore species were observed to strand within a two- to three-day period.

The US Navy indicated that from January 12-14 some unit level training with MFA sonar was conducted by vessels that were 93 to 185 km from Oregon Inlet. An expeditionary strike group was also conducting exercises to the southeast, but the closest point of active sonar transmission to the inlet was 650 km away. The unit level activities were not unusual for the area or time of year and the vessels were not involved in ASW exercises. Marine mammal observers on board the vessels did not detect any marine mammals during the period of unit level training. No sonar transmissions were made on January 15-16.

The National Weather Service reported that a severe weather event moved through North Carolina on January 13 and 14 (Figure 6-9). The event was caused by an intense cold front that moved into an unusually warm and moist air mass that had been persisting across the eastern United States for about a week. The weather caused flooding in the western part of the state, considerable wind damage in central regions of the state, and at least three tornadoes that were reported in the north central part of the state.

Over a two-day period (January 16-17), 2 dwarf sperm whales, 27 pilot whales, and the minke whale were necropsied and tissue samples collected. Twenty-five of the stranded cetacean heads

were examined; two pilot whale heads and the heads of the dwarf sperm whales were analyzed by CT.
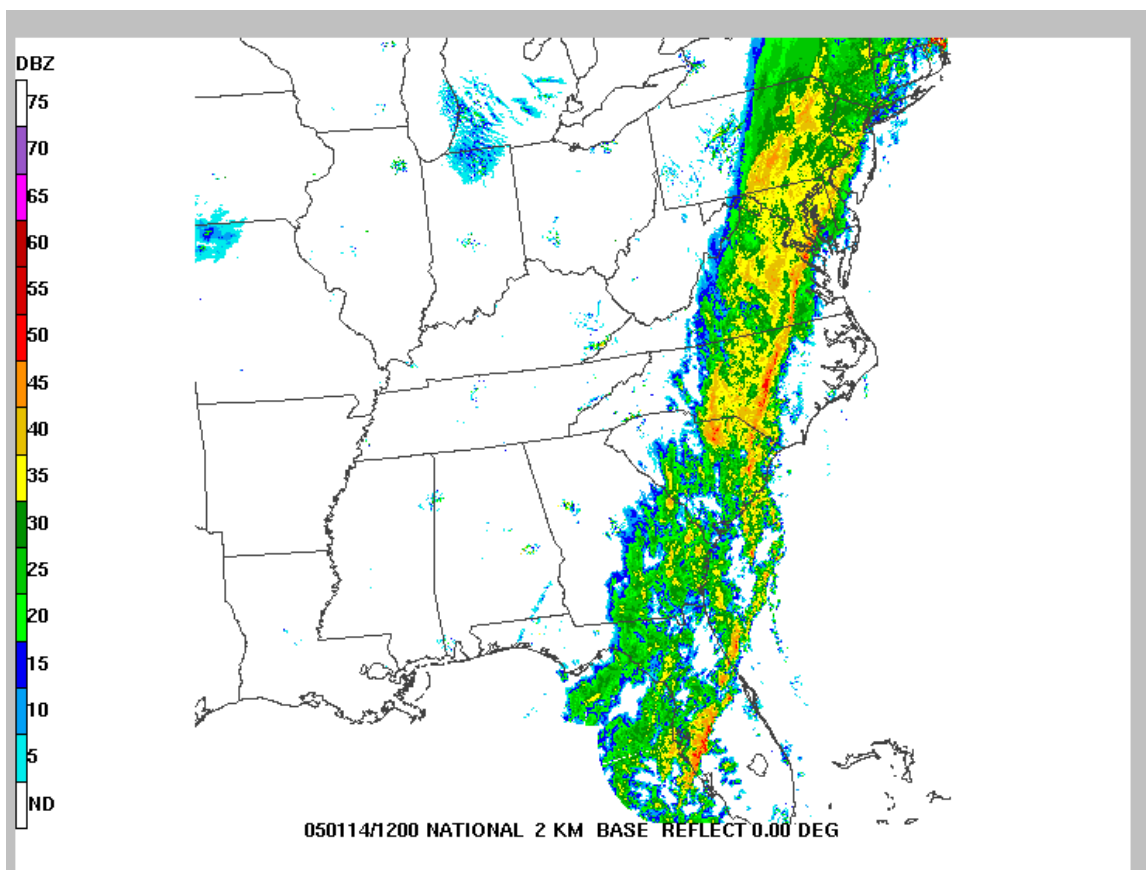
Figure 6-9: Regional radar imagery for the east coast (including North Carolina) on July 14, 2005. (The time of the image is approximately 7:00 a.m.)

Findings

The pilot whales and dwarf sperm whale were not emaciated, but the minke whale, which was believed to be a dependent calf, was emaciated. Many of the animals were on the beach for an extended period of time prior to necropsy and sampling, and many of the biochemical abnormalities noted in the animals were suspected of being related to the stranding and prolonged time on land. Lesions were observed in all of the organs, but there was no consistency across species. Musculoskeletal disease was observed in two pilot whales and cardiovascular disease was observed in one dwarf sperm whale and one pilot whale. Parasites were a common finding in the pilot whales and dwarf sperm whales but were considered consistent with the expected parasite load for wild odontocetes. None of the animals exhibited traumas similar to those observed in prior stranding events associated with MFA sonar. Specifically, there was an absence of auditory system trauma and no evidence of distributed and widespread bubble lesions or fat emboli, as was previously observed (Fernández et al. 2005).

Sonar transmissions prior to the strandings were limited in nature and did not share the concentration identified in previous events associated with MFA sonar use (Evans and England, 2001). The operational/environmental conditions were also dissimilar (e.g., no constrictive channel and a limited number of ships and sonar transmissions). NMFS noted that environmental

conditions were favorable for a shift from up-welling to down-welling conditions, which could have contributed to the event. However, other severe storm conditions existed in the days surrounding the strandings and the impact of these weather conditions on at-sea conditions is unknown. No harmful algal blooms were noted along the coastline.

Conclusions

All of the species involved in this stranding event are known to occasionally strand in this region. Although the cause of the stranding could not be determined, several whales had preexisting conditions that could have contributed to the stranding. Cause of death for many of the whales was likely due to the physiological stresses associated with being stranded. A consistent suite of injuries across species, which was consistent with prior strandings where sonar exposure is expected to be a causative mechanism, was not observed.

NMFS was unable to determine any causative role that sonar may have played in the stranding event. The acoustic modeling performed, as in the Hanalei Bay incident, was hampered by uncertainty regarding the location of the animals at the time of sonar transmissions. However, as in the Hanalei Bay incident, the response of the animals following the cessation of transmissions would imply a flight response that persisted for many hours after the sound source was no longer operational. In contrast, the presence of a severe weather event passing through North Carolina during January 13 and 14 is a possible, if not likely, contributing factor to the North Carolina UME of January 15.

6.4.4 Stranding Section Conclusions

Marine mammal strandings have been a historic and continuing occurrence that is attributed to a variety of causes. Over the last fifty years, increased awareness and reporting has led to more information about the species affected and has raised concerns about anthropogenic sources of stranding. While there have been some marine mammal mortalities potentially associated with MFA sonar exposure (primarily limited to certain species of beaked whale), the significance and actual causative reason for any impacts is subject to continued investigation. ICES (2005a) noted that, taken in context of marine mammal populations in general, sonar is neither a major threat nor a significant contributor to the overall ocean noise budget. However, continued research based on sound scientific principles is needed in order to avoid speculation as to stranding causes and to further our understanding of the potential effects resulting from marine mammals being exposed to military MFA sonar (Bradshaw et al. 2006; ICES 2005b; Barlow and Gisiner, 2006; Cox et al. 2006).

6.5 Non-Sonar Acoustic Impacts and Non-Acoustic Impacts

6.5.1.1 Ship Noise

Increased number of ships operating in the area will result in increased sound from vessel traffic. Marine mammals react to vessel-generated sounds in a variety of ways. Some respond negatively by retreating or engaging in antagonistic responses while other animals ignore the stimulus altogether (Watkins 1986; Terhune and Verboom 1999). Most studies have ascertained the short-term response to vessel sound and vessel traffic (Watkins et al. 1981; Baker et al. 1983; Magalhães et al. 2002); however, the long-term implications of ship sound on marine mammals is largely unknown (NMFS 2007). Anthropogenic sound, especially around regional commercial shipping hubs has increased in the marine environment over the past 50 years (Richardson, et al.

1995; Andrew et al. 2002; NRC 2003; Hildebrand 2004; NRC 2005). This sound increase can be attributed primarily to increases in vessel traffic as well as sound from other human sources (Richardson, et al. 1995; NRC 2005). NRC (2005) has a thorough discussion of both human and natural underwater sound sources.

Given the current ambient sound levels in the NWTRC marine environment, the amount of sound contributed by the use of Navy vessels in the proposed exercises is very low. In addition, as opposed to commercial vessels, Navy ships are purposely designed and engineered for the lowest underwater acoustic signature possible given the limits of current naval shipbuilding technology. The goal with ship silencing technology is to limit the amount of sound a Navy vessel radiates that could be used by a potential adversary for detection. Given these factors, it is anticipated that any marine mammals exposed may exhibit either nor reactions or only short-term reactions, and would not suffer any long-term consequences from ship sound.

6.5.1.2 Effects from Gunfire

SINKEXs and other NWTRC activities include surface ship gunfire. Although fired above the deck, energy from 5"/54 caliber Naval gunfire can propagate into the water from the muzzle blast, through the hull, and from the shell traveling supersonically along its trajectory. Firing of the deck gun produces a shock wave in air that propagates away from the muzzle in all directions, including toward the air/water surface. Effects of greatest concern due to this shock wave are the peak pressure, impulse, and noise transfer from air into water because the species of concern here spend almost all of their time underwater. The design of naval ships is such that the muzzle does not protrude over the side of the ship; therefore, energy traveling directly down is reflected off of the deck. The blast wave impinging on the water will undergo spherical spreading until it reaches the side of the ship. The blast wave diffracts around the ship structure and the blast wave will be less than the source when it enters the water. Much of the blast energy that does reach the water's surface is reflected back into the air if the incident angle is greater than 13.7° (critical angle) from the perpendicular (Urick, 1983). Direct measurements of shock wave pressures and acoustic energy were made below the 5"/54 caliber gun while firing (Naval Surface Warfare Center 2000; Yagla and Stiegler, 2003).   The impulse of the blast wave transferred across the air-sea interface was measured at approximately 4.3 psi-msec, whereas potentially harmful levels are greater than 13 psi-msec at shallow depths. Calculated peak SPL approximately 10 m below the gun muzzle at the air-sea interface was between 195 and 205 dB re:1μPa, and 100 m down-range, near the surface, the peak SPL was calculated to be lower than 186 dB re 1μPa (Pater 1981; Yagla 1986; Yagla and Stiegler 2003). The greatest EFD level in the 1/3 octave above 10 Hz was calculated for a point directly below the muzzle as 190 dB re:1μPa^2-s and drops below 182 dB re 1μPa^2-s at 30 m underwater. A gun blast also sends energy through the ship structure that can enter the water and propagate away from the ship. This effect was also investigated in conjunction with the measurement of 5" gun blasts described above (Naval Surface Warfare Center, 2000; Yagla and Stiegler 2003b). The structure-borne component of the energy, when measured in the water, consisted of low-level oscillations that preceded the main pulse from the air blast impinging upon the water. The component of energy transmitted through the ship to the water for a typical round was found to be about 6% of that from the air blast impinging on the water discussed above. Noise transmitted from the gun through the hull into the water was therefore judged to be insignificant during the study and is not analyzed further.

6.5.1.3 Noise from Sonic Boom of Shell

The sound generated by a shell in its flight at supersonic speeds above the water is transmitted into the water in much the same way as a muzzle blast. During a study of the bow shock environment from 5" and 16" gun projectiles, the highest in-air SPL was measured at 145.1 dB re: 20 mPa , with the preponderance of noise at SPLs between 90 and 120 dB re: 20 µPa (Pater, 1981; Miller, 1991). The initial boom of the shell, once it has left the barrel, has a peak pressure in the water nearest the gun barrel of 195 dB re: 1 µPa (roughly 0.8 psi). The calculated 1/3 octave band EFD level containing the most energy above 10 Hz from a single shell is 180 dB re: 1 mPa^2-s. If the shell is fired horizontally, the traveling shell transmits those pressures and energy along its trajectory in air with essentially the same noise levels reaching the air-water interface along the path of the shell. A typical line of flight initially increases in altitude until it reaches the midpoint of the trajectory, at which point the altitude decreases as the shell nears the target. The underwater noise levels would decrease logarithmically from the initial levels mentioned above as the shell height increases above the water surface. The region of underwater noise influence from a single traveling shell is relatively small, diminishes quickly as the shell gains altitude, and is of brief duration. Additionally, watch standers observe waters surrounding the ship to ensure that marine animals are not nearby (paragraph 6.2). Therefore, noise from the sonic boom of the traveling shell is not likely to adversely affect marine mammals.

Noise produced during gunfire may disturb animals in the vicinity of the ship. Because the noise from shooting at the target dissipates rapidly, no significant disruption of behavior is expected from 5"/54 caliber and 76-mm gunfire. Even though gunfire noise may prove to be a source of annoyance, the duration is relatively brief and the severity of its effects would be insignificant. Injury from the shock wave produced during 5"/54 caliber and 76-mm naval gunfire is not likely because in-water impulses at ranges close to the muzzle are well below those found to be harmful at shallow depths. Additionally, temporary effects, such as those to the auditory system, are not likely because the region of noise influence from a single shot is relatively small and watchstanders observe waters surrounding the ship to ensure that marine animals are not nearby the ship. Therefore, muzzle blast noise is not likely to adversely affect marine mammals.

6.5.1.4 Noise Effects of On-target Explosions

Detonation of ordnance within a target such as one used for a SINKEX can send sound energy into the water via two paths. The first path is internal, through the ship, and the second path is external, via the air. In the spaces where the detonation occurs, the pressure may be large enough to deform and rupture nearby bulkheads, transferring energy directly through the hull into the water. For sufficiently large charges, failure of the weather bulkhead can result in the formation of a large hole through which shock wave energy can exit into the atmosphere and subsequently into the water.

As the products of the explosion expand away from the point of detonation, a strong shock wave moves radially away through the ship. When the shock wave impinges on a surface, such as decks and bulkheads, it causes dishing, buckling, and collapsing (Charles 1990; Anonymous 2004). The plating moves impulsively away from the impact point, displacing air in adjoining spaces. Through sequential plate deformation and air motion, the effects of the explosion are transmitted through the ship, eventually deforming the hull and transmitting a sound wave that moves away from the ship through the water. Each transfer of energy from air to steel and steel to air involves losses of energy due to impedance mismatches of the mediums and the

mechanical deformation of steel. For example, the transfer of energy from steel to air is very inefficient with approximately 0.01% of the energy transmitted through the steel-air interface (Yagla 2003). After several transfers through the ship, the energy will transfer into the water. The coefficient for energy transfer from steel to water is better than that of steel to air, but is still relatively inefficient at about 10%. During one analysis of an explosive charge set within a Navy vessel, there was a factor of less than 10 -17 fraction of the initial energy transferred from detonation within a compartment to the water via the hull. Analysts described the transfer of energy into the water as "miniscule" (Yagla 2003).

When the high-pressure detonation products expand, a breech can be created in the hull or the hole through which the ordnance entered can be expanded. The failure is so sudden that the products of detonation drive a shock wave through the hole and exit into the surrounding atmosphere. Energy transfer via the breech in the weather surface is influenced by proximity of the detonation to it (Yagla 2003). For example, more energy is transferred into the water by explosions nearer the weather surface than those deeper inside of the ship. However, even a detonation directly above the water surface can be 1000 times less hazardous than a similar charge below the surface (Goertner 1978); therefore, effects reduce substantially as the explosion location moves within the ship. A considerable amount of the total energy is absorbed by the ship in the form of heat and deformation of steel plating described above. A fraction of the total energy released by the detonation exits through the hole and impinges upon the water, but is completely reflected with no transfer of energy if the incident angle is greater than critical (13.7degree), a phenomenon known as acoustic cut off (Urick 1983). Finally, a 3dB loss results from the insertion of the shock wave into the water further reducing energy transfer from initial levels (Yagla 2003).

When the two paths for noise energy from on-target detonations were considered, only insignificant amounts of energy were found to enter the water as noise. Therefore, blast waves and noise energy generated by on-target detonations were found to have no effect on marine mammals.

6.5.1.5 Aerial Bomb Explosive Fragments

Blast injuries from exploding warheads may be caused by the entrance of propelled fragments into the body when in very close proximity to the explosion (Phillips and Richmond 1990; Stuhmiller et al. 1990). A study was conducted about the behavior of propelled fragments using MK 82 bombs detonated at various water depths (O'Keeffe and Young 1984; Swisdak Jr. and Montaro 1992). The MK 82 ballistic bomb has a warhead roughly equivalent in Net Explosive Weight (NEW) as the MK-48 ADCAP torepdo, and therefore is comparable. When the MK 82 was exploded at a depth of 40 ft (12 m), no fragments were seen escaping the water, indicating that they all traveled in plumes underwater extending about 100 ft (30 m) (Swisdak Jr. and Montaro 1992). Fragments from the underwater explosion were larger than those produced during in-air blasts and decelerated rapidly through the water (O'Keeffe and Young 1984; Swisdak Jr. and Montaro 1992). The torpedo explosion is also somewhat obstructed by the surfaced target, which shields the upwardly moving fragments. Therefore, the possibility that propelled fragments would physically impact an animal near the target is negligible at all test sites given the small footprint and Navy protective measures.

6.5.1.6 Munitions Constituents

Chemical products of underwater explosions are initially confined to a thin, circular area called the surface pool. It is estimated that 100% of the solid explosion products and 10% of the gases remain in the pool (DoN 2001a). After the turbulence of the explosion has dispersed, the pool stabilizes and the chemical products are diluted and become undetectable. Because of continued dispersion and mixing, no buildup of explosion products in the water column would occur. The effect of chemical products from explosions and from the vessel sinking are considered to be negligible (DoN 2001a). Initial concentrations of the chemical by-products are not hazardous to marine life. In addition, any residual by-products will be rapidly dispersed in the ocean (DoN 2001a). The USEPA considered the contaminant levels released during the sinking of the target to be within the standards of the MPRSA. Munitions constituents released during a SINKEX do not appear to pose a threat to marine mammals and no further analysis is necessary.

6.5.1.7 Ship Strikes

Collisions with commercial and Navy ships can cause major wounds and may occasionally cause fatalities to cetaceans. The most vulnerable marine mammals are those that spend extended periods of time at the surface in order to restore oxygen levels within their tissues after deep dives (e.g., sperm whale). In addition, some baleen whales, such as the northern right whale and fin whale swim slowly and seem generally unresponsive to ship sound. Northern right whales have been documented to respond to alarm stimuli above 133 dB re 1μPa by surfacing. The combination of a lack of response to ship noise and sensitivity to alarming stimuli may make them more susceptible to ship strikes (Nowacek et al. 2004). Smaller marine mammals-for example, Pacific white-side dolphins and common dolphins move quickly throughout the water column and are often seen riding the bow wave of large ships. Marine mammal responses to vessels may include avoidance and changes in dive pattern (NRC 2003).

The Navy has adopted mitigation measures that reduce the potential for collisions with surfaced marine mammals (See Chapter 11). These standard operating procedures include: (1) use of lookouts trained to detect all objects on the surface of the water, including marine mammals; (2) reasonable and prudent actions to avoid the close interaction of Navy assets and marine mammals; and (3) maneuvering to keep away from any observed marine mammal. Based on these standard operating procedures, collisions with marine mammals are not expected. This assessment is also applicable to discussions of Alternatives 1 and 2.

6.5.1.8 Torpedoes

There is a negligible risk that a marine mammal could be struck by a torpedo during ASW training activities. This conclusion is based on (1) review of torpedo design features, and (2) review of a large number of previous naval exercise ASW torpedo activities. The acoustic homing programs of torpedoes are designed to detect either the mechanical sound signature of the submarine or active sonar returns from its metal hull with large internal air volume interface. The torpedoes are specifically designed to ignore false targets. As a result, their homing logic does not detect or recognize the relatively small air volume associated with the lungs of marine mammals. They do not detect or home to marine mammals. The Navy has conducted exercise torpedo activities since 1968. At least 14,322 exercise torpedo runs have been conducted since 1968. There have been no recorded or reported instances of a marine species strike by an exercise torpedo. Every exercise torpedo activity is monitored acoustically by on-scene range personnel listening to range hydrophones positioned on the ocean floor in the immediate vicinity

of the torpedo activity. After each torpedo run, the recovered exercise torpedo is thoroughly inspected for any damage. The torpedoes then go through an extensive production line refurbishment process for re-use. This production line has stringent quality control procedures to ensure that the torpedo will safely and effectively operate during its next run. Since these exercise torpedoes are frequently used against manned Navy submarines, this post activity inspection process is thorough and accurate. Inspection records and quality control documents are prepared for each torpedo run. This post exercise inspection is the basis that supports the conclusion of negligible risk of marine mammal strike. Therefore, there will be no significant impact and no significant harm to marine mammals resulting from interactions with torpedoes during NWTRC activities under the No Action Alternative, Alternative 1, or Alternative 2. The probability of direct strike of torpedoes associated with NWTRC training is negligible and therefore will have no effect on ESA-listed marine mammal species.

6.5.1.9 Military Expendable Material

Marine mammals are subject to entanglement in expended materials, particularly anything incorporating loops or rings, hooks and lines, or sharp objects. Most documented cases of entanglements occur when whales encounter the vertical lines of fixed fishing gear. This section analyzes the potential effects of expended materials on marine mammals

The Navy endeavors to recover expended training materials. Notwithstanding, it is not possible to recover all training debris, and some may be encountered by marine mammals in the waters of the NWTRC. Debris related to military activities that is not recovered generally sinks; the amount that might remain on or near the sea surface is low, and the density of such debris in the NWTRC would be very low. Types of training debris that might be encountered include: parachutes of various types (e.g., those employed by personnel or on targets, flares, or sonobuoys); torpedo guidance wires, torpedo "flex hoses;" cable assemblies used to facilitate target recovery; sonobuoys; and Expendable Mobile Acoustic Training Target s (EMATT)

Entanglement in military-related debris was not cited as a source of injury or mortality for any marine mammals recorded in a large marine mammal and sea turtle stranding database for California waters. Range debris is highly unlikely to affect marine mammal species in the NWTRC. The following discussion addresses categories of debris.

6.5.1.9.1 Sonobuoys

A sonobuoy is approximately 5 in (13 cm) in diameter, 3 ft (1 m) long, and weighs between 14 and 39 lbs (6 and 18 kg), depending on the type. In addition, aircraft-launched sonobuoys deploy a nylon parachute of varying sizes, ranging from 1.6 to 3.8 ft^2 (0.15 to 0.35 m^2). The shroud lines range from 12 to 21 in (0.30 to 0.53 m) in length and are made of either cotton polyester with a 30-lb (13.6-kg) breaking strength or nylon with a 100-lb (45.4-kg) breaking strength. All parachutes are weighted with a 2 ounce (0.06-kg) steel material weight, which causes the parachute to sink from the surface within 15 minutes. At water impact, the parachute assembly, battery, and sonobuoy will sink to the ocean floor where they will be buried into its soft sediments or land on the hard bottom where they will eventually be colonized by marine organisms and degrade over time. These components are not expected to float at the water surface or remain suspended within the water column. Over time, the amount of materials will accumulate on the ocean floor. However, the active sonar activities using sonobuoys will not likely occur in the exact same location each time. Additionally, the materials will not likely settle in the same vicinity due to ocean currents.

6.5.1.9.2 Parachutes

Aircraft-launched sonobuoys, flares, torpedoes, and EMATTs deploy nylon parachutes of varying sizes. As described above, at water impact, the parachute assembly is expended and sinks, as all of the material is negatively buoyant. Some components are metallic and will sink rapidly. Entanglement and the eventual drowning of a marine mammal in a parachute assembly would be unlikely, since such an event would require the parachute to land directly on an animal, or the animal would have to swim into it before it sinks. The expended material will accumulate on the ocean floor and will be covered by sediments over time, remaining on the ocean floor and reducing the potential for entanglement. If bottom currents are present, the canopy may billow (bulge) and pose an entanglement threat to marine animals with bottom-feeding habits; however, the probability of a marine mammal encountering a submerged parachute assembly and the potential for accidental entanglement in the canopy or suspension lines is considered to be unlikely.

6.5.1.9.3 Torpedoes

The Mk-48 torpedo is approximately 19 ft (5.8 m) long and 21 in (53 cm) in diameter. The only Mk-48 use in the NWTRC is in the anti-ship mode during a SINKEX. The MK-48 torpedo is equipped with a guidance wire that facilitates final command and control functions as the torpedo departs the submarine. Up to 28 km (15 miles [mi]) of wire is deployed during a run, which will sink to the sea floor at the conclusion of the torpedo run. DoN (1996) analyzed the potential entanglement effects of torpedo control wires on sea turtles. The Navy analysis concluded that the potential for entanglement effects will be low for the following reasons, which apply also to potential entanglement of marine mammals:

The guidance wire is a very fine, thin-gauge copper-cadmium core with a polyolefin coating. The tensile breaking strength of the wire is a maximum of 42 lb (19 kg) and can be broken by hand. With the exception of a chance encounter with the guidance wire while it was sinking to the sea floor (at an estimated rate of 0.5 ft/sec (0.2 m/sec), a marine animal would be vulnerable to entanglement only if its diving and feeding patterns place it in contact with the bottom.

The torpedo control wire is held stationary in the water column by drag forces as it is pulled from the torpedo in a relatively straight line until its length becomes sufficient for it to form a chain-like droop. When the wire is cut or broken, it is relatively straight and the physical characteristics of the wire prevent it from tangling, unlike the monofilament fishing lines and polypropylene ropes identified in the entanglement literatures.

While it is possible that a marine mammal would encounter a torpedo guidance wire as it sinks to the ocean floor, the likelihood of such an event is considered remote, as is the likelihood of entanglement after the wire has descended to and rests upon the ocean floor.

Given the low potential probability of marine mammal entanglement with guidance wires, the potential for any harm or harassment to these species is extremely low. Therefore, there will be no significant impact to marine mammals resulting from interactions with torpedo guidance wire during NWTRC activities.

In addition to the guidance wire, the MK-48 also uses and expends a flex hose. The flex hose protects the torpedo guidance wire and prevents it from forming loops as it leaves the torpedo tube of a submarine. Improved flex hoses or strong flex hoses will be expended during torpedo firings. DoN (1996) analyzed the potential for the flex hoses to affect sea turtles. This analysis

concluded that the potential entanglement effects to marine animals will be insignificant for reasons similar to those stated for the potential entanglement effects of control wires:

- Due to weight, flex hoses will rapidly sing to the bottom upon release. With the exception of a chance encounter with the flex hose while it was sinking to the sea floor, a marine mammal would be vulnerable to entanglement only if its diving and feeding patterns placed it in contact with the bottom.

- Flex hoses are designed to prevent entanglement of the guidance wire when the torpedo is launched, and therefore are somewhat rigid. Due to its stiffness, the 250-ft (76 m) flex hose will not form loops that could entangle marine mammals.

Therefore, there will be no notable impact to marine mammals resulting from interactions with torpedo flex hoses during NWTRC activities.

6.5.1.9.4 Expendable Mobile ASW Training Target (EMATT)

The Navy uses the EMATT acoustic training target during ASW sonar training exercises. EMATTs are approximately 5 by 36 inches (in) (12 by 91 centimeters [cm]) and weigh approximately 21 pounds (lbs). Given the small size of EMATTs, coupled with the low probability that an animal would occur at the immediate location of deployment and reconnaissance, provide little potential for a direct strike.

EMATTs, their batteries, parachutes, and other components will scuttle and sink to the ocean floor and will be covered by sediments over time. In addition, the small amount of expended material will be spread over a relatively large area. Due to the small size and low density of the materials, these components are not expected to float at the water surface or remain suspended within the water column. Over time, the amount of materials will accumulate on the ocean floor, but due to ocean currents, the materials will not likely settle in the same vicinity. There will be minimal impact to marine habitat from expended EMATTs or their components.

6.5.1.9.5 Other Falling Expendable Material

Potential debris created during a SINKEX is primarily metal from the target and shell fragments. Metal debris sinks quickly and settles to the bottom. Sperm whales are known to ingest foreign objects, and they may feed at times near the bottom where they may encounter debris (Würsig et al. 2000). Baleen whales occasionally feed on benthic organisms, but only in shallow bank waters (Hain et al. 1995). However, there is little possibility that debris settling on the bottom at depths greater than 6,000 ft (1,829 m) where SINKEXs occur will pose any hazard to sperm whales, or baleen whales. Very little evidence of the target ship can be seen immediately after submergence of the ship during a SINKEX. No debris will be released during the SINKEX as result of dumping or disposal from support ships. Debris created during a SINKEX will not pose an ingestion or entanglement threat to listed species and therefore will have no effect on them.

In addition, marine mammals are widely dispersed in the NWTRC, therefore, there is an extremely low probability of injury to a marine mammal from falling debris such as munitions constituents, inert ordnance, or targets. The probability of negative interaction from direct strike, sound, or other energy by expendable material is remote. Therefore, there will be minimal impact to marine mammals resulting from interactions with targets, or exercise torpedoes during NWTRC activities.

6.6   Estimated ASW Effects on Marine Mammals

6.6.1 Model Results Explanation

Acoustic exposures are evaluated based on their potential direct effects on marine mammals, and these effects are then assessed in the context of the species biology and ecology to determine if there is a mode of action that may result in the acoustic exposure warranting consideration as a harassment level effect.

It is estimated that 129,111 marine mammals will exhibit responses NMFS will classify as behavioral harassment (MMPA Level B) as a result of MFA/HFA sonar use (128,583 using the Risk Function and 528 from TTS). One marine mammal (harbor seal) will be exposed to sonar in excess of permanent threshold shift (PTS) threshold indicative of MMPA Level A harassment. The modeled sonar exposure numbers by species are presented in Table 6-7.

The modeling indicates 262 annual exposures (Table 6-8) to pressure or acoustics from explosive sources that could result in a sub-TTS behavioral response (threshold of 177 dB re $1\mu Pa^2$-s) and 197 that could cause TTS (threshold of 182 dB re $1\mu Pa^2$-s or 23 psi). The total number of exposures from explosives that NMFS would classify as MMPA Level B harassment would be 459. Modeling indicates 12 exposures from explosive sources that could cause slight injury, resulting in MMPA Level A harassment and no exposures causing mortality.

These exposure modeling results are estimates of marine mammal sonar exposures without consideration of standard mitigation and monitoring procedures. The implementation of the mitigation and monitoring procedures, as addressed in Chapter 11, will minimize the potential for marine mammal exposures to MFA and HFA sonar.

A large body of research on terrestrial animal and human response to airborne sound exists, but results from those studies are not readily applicable to the development of behavioral criteria and thresholds for marine mammals. Differences in hearing thresholds, dynamic range of the ear, and the typical exposure patterns of interest (e.g., human data tend to focus on 8-hour-long exposures), and the difference between acoustics in air and in water make extrapolation of human sound exposure standards inappropriate.

Behavioral observations of marine mammals exposed to anthropogenic sound sources exists, however, there are few observations and no controlled measurements of behavioral disruption of cetaceans caused by sound sources with frequencies, waveforms, durations, and repetition rates comparable to those employed by the tactical sonars described in this EIS/OEIS (Deecke 2006) or for multiple explosives. Controlled studies in the laboratory have been conducted to determine physical changes (TTS) in hearing of marine mammals associated with sound exposure (Finneran et al. 2001, 2003, 2005). Research on behavioral effects has been difficult because of the difficulty and complexity of implementing controlled conditions.

At the present time there is no general scientifically accepted consensus on how to account for behavioral effects on marine mammals exposed to anthropogenic sounds including military sonar and explosions (National Research Council [NRC] 2003, 2005). While the first elements in Figure 6-9 can be easily defined (source, propagation, receiver) the remaining elements (perception, behavior, and life functions) are not well understood given the difficulties in studying marine mammals at sea (NRC 2005). The NRC (2005) acknowledges "there is not one case in which data can be integrated into models to demonstrate that noise is causing adverse affects on a marine mammal population."

For purposes of predicting the number of marine mammals that will be behaviorally harassed or sustain either TTS or PTS, the Navy uses an acoustic impact model process with numeric criteria agreed upon with the NMFS.

There are some caveats necessary to understand in order to put these exposures in context. For instance, (1) significant scientific uncertainties are implied and carried forward in any analysis using marine mammal density data as a predictor for animal occurrence within a given geographic area; (2) there are limitations to the actual model process based on information available (animal densities, animal depth distributions, animal motion data, impact thresholds, type of sound source and intensity, behavior (involved in reproduction or foraging), previous experience and supporting statistical model); and determination of what constitutes a significant behavioral effect in a marine mammal is still unresolved (National Research Council 2005). The sources of marine mammal densities used in this LOA application are derived from NMFS surveys (Barlow 2003, 2006; Mobley et al. 2001; Ferguson and Barlow 2001; 2003; DoN 2007a). These ship board surveys cover significant distance around the Hawaiian Islands, Eastern Tropical Pacific and the Mariana Islands. Although survey design includes statistical placement of survey tracks, the survey itself can only cover so much ocean area. Post-survey statistics are used to calculate animal abundances and densities (Barlow and Forney 2007). There is often significant statistical variation inherent within the calculation of the final density values depending on how many sightings were available during a survey. Occurrence of marine mammals within any geographic area including the Mariana Islands is highly variable and strongly correlated to oceanographic conditions, bathymetry, and ecosystem level patterns (prey abundance and distribution) (Benson et al. 2002; Moore et al. 2002; Tynan 2005; Redfern 2006).

For some species, distribution may be even more highly influenced by relative small scale biological or oceanographic features over both short and long-term time scales (Ballance et al. 2006; Etnoyer et al. 2006; Ferguson et al. 2006; Skov et al. 2007). Unfortunately, the scientific understanding of some large scale and most small scale processes thought to influence marine mammal distribution is incomplete.

Given the uncertainties in marine mammal density estimation and localized distributions, the Navy's acoustic impact models can not currently take into account locational data for any marine mammals within specific areas of the NWTRC. To resolve this issue and allow modeling to precede, animals are "artificially and uniformly distributed" within the modeling provinces described in Appendix B.

6.6.1.1 Behavioral Responses

The intensity of the behavioral responses exhibited by marine mammals depends on a number of conditions including the age, reproductive condition, experience, behavior (foraging or reproductive), species, received sound level, type of sound (impulse or continuous) and duration (including whether exposure occurs once or multiple times) of sound (Reviews by Richardson et al. 1995a; Wartzok et al. 2003; Cox et al. 2006, Nowacek et al. 2007; Southall et al. 2007) (Figure 6-10). Many behavioral responses may be short term (seconds to minutes orienting to the sound source or over several hours if they move away from the sound source) and of little immediate consequence for the animal. However, certain responses may lead to a stranding or mother-offspring separation (Baraff and Weinrich 1994; Gabriele et al. 2001). Active sonar exposure is brief as the ship is constantly moving and the animal will likely be moving as well.

Generally the louder the sound source the more intense the response although duration is also very important (Southall et al. 2007).

According to the severity scale response spectrum (Figure 6-10) proposed by Southall et al. (2007), responses classified as from 0-3 are brief and minor, those from 4-6 have a higher potential to affect foraging, reproduction, or survival and those from 7-9 are likely to affect foraging, reproduction and survival. Sonar and explosive mitigation measures (sonar power-down or shut-down zones and explosive exclusion zones) would likely prevent animals from being exposed to the loudest sonar sounds or explosive effects that could potentially result in TTS or PTS and more intense behavioral reactions (i.e. 7-9) on the response spectrum.

Behavioral Responses

No Effect ← 0 1 2 3 4 5 6 7 8 9 → **Severe**

0 - No observable response
1- Brief orientation response (investigation / visual orientation)
2 - Moderate or multiple orientation behaviors
  - Brief or minor cessation / modification of vocal behavior
  - Brief or minor change in respiration rates
3 - Prolonged orientation behavior
  - Individual alert behavior
  - Minor changes in locomotion speed, direction, and/or dive profile but no avoidance of sound source
  - Moderate change in respiration rate
  - Minor cessation or modification of vocal behavior (duration < duration of source activity), including the Lombard Effect
4 - Moderate changes in locomotion speed, direction, and/or dive profile, but not avoidance of sound source
  - Brief, minor shift in group distribution
  - Moderate cessation or modification of vocal behavior (approximate duration of source activity)
5 - Extensive or prolonged changes in locomotion speed, direction, and / or dive profile, but not avoidance in sound source
  - Moderate shift in group distribution
  - Change in inter-animal distance and / or group size (aggregation or separation)
  - Prolonged cessation or modification of vocal behavior (duration > duration of source activity)
6 - Minor or moderate individual and / or group avoidance of sound source
  - Brief or minor separation of females and dependent offspring
  - Aggressive behavior related to noise exposure (e.g., tail / flipper slapping, fluke display, jaw clapping / gnashing teeth, abrupt directed movement, bubble clouds)
  - Extended cessation or modification of vocal behavior
  - Visible startle response
  - Brief cessation of reproductive behavior
7 - Excessive or prolonged aggressive behavior
  - Moderate separation of females and dependent offspring
  - Clear antipredator response
  - Severe and / or sustained avoidance of sound source
  - Moderate cessation of reproductive behavior
8 - Obvious aversion and / or progressive sensitization
  - Prolonged or significant separation of females and dependent offspring with disruption of acoustic reunion mechanism
  - Long-term avoidance of area (> source activity)
  - Prolonged cessation of reproductive behavior
9 - Outright panic, fight, stampede, attack of conspecifics, or stranding event
  - Avoidance behavior related to predator detection

Source: Southall et al., 2007

Figure 6-10. Proposed Marine Mammal Response Severity Scale Spectrum to Anthropogenic Sounds In Free Ranging Marine Mammals

There are little data on the consequences of sound exposure on vital rates of marine mammals. Several studies have shown the effects of chronic noise (either continuous or multiple pulses) on marine mammal presence in an area exposed to seismic survey airguns or ship noise (e.g., Malme et al. 1984; McCauley et al. 1998; Nowacek et al. 2004). MFA/HFA sonar use in the NWTRC is not new given the current hull-mounted sonar employs the same basic sonar equipment and having the same output for over approximately 30 years. Given this history, the Navy believes that risk to marine mammals from sonar training is low.

Even for more cryptic species such as beaked whales, the main determinant of causing a stranding appears to be exposure in a limited egress areas (a long narrow channel) with multiple ships. The result is that animals may be exposed for a prolonged period rather than several sonar pings over several minutes and the animals having no means to avoid the exposure. Under these specific circumstances and conditions, MFA sonar is believed to have contributed to the stranding resulting in indirectly caused mortality of a small number of beaked whales in locations other than the NWTRC. There are no limited egress areas (long narrow channels) in the NWTRC, therefore, it is unlikely that the proposed sonar use would result in any strandings. Although the Navy has substantially changed operating procedures to avoid the aggregate of circumstances that may have contributed to previous strandings, it is important that future unusual stranding events be reviewed and investigated so that any human cause of the stranding can be understood and avoided.

There have been no beaked whales strandings in the NWTRC associated with the use of MFA/HFA sonar. This is a critically important contextual difference between the NWTRC and areas of the world where strandings have occurred (Southall et al. 2007). While the absence of evidence does not prove there have been no impacts on beaked whales, decades of history with no evidence cannot be lightly dismissed.

6.6.1.2   TTS

A TTS is a temporary recoverable, loss of hearing sensitivity over a small range of frequencies related to the sound source to which it was exposed. The animal may not even be aware of the TTS and does not become deaf, but requires a louder sound stimulus (relative to the amount of TTS) to detect that sound within the affected frequencies. TTS may last several minutes to several days and the duration is related to the intensity of the sound source and the duration of the sound (including multiple exposures). Sonar exposures are generally short in duration and intermittent (several sonar pings per minute from a moving ship), and with mitigation measures in place, TTS in marine mammals exposed to MFA or HFA sonar and underwater detonations are unlikely to occur. There is currently no information to suggest that if an animal has TTS, that it will decrease the survival rate or reproductive fitness of that animal. TTS range from a MFA sonar's 235 dB source level one second ping is approximately 361 ft. (110 m) from the bow of the ship under nominal oceanographic conditions.

6.6.1.3   PTS

A PTS is non-recoverable, results from the destruction of tissues within the auditory system, and occurs over a small range of frequencies related to the sound exposure. The animal does not become deaf but requires a louder sound stimulus (relative to the amount of PTS) to detect that sound within the affected frequencies. Sonar exposures are generally short in duration and intermittent (several sonar pings per minute from a moving ship) and with mitigation measures in place, PTS in marine mammals exposed to MFA or HFA sonar is unlikely to occur. There is

currently no information to suggest that if an animal has PTS, it decreases the survival rate or reproductive fitness of that animal. The distance to PTS from a MFA sonar's 235 dB source level one second ping is approximately 33 ft. (10 m) from the bow of the ship under nominal oceanographic conditions.

6.6.1.4 Population Level Effects

Some NWTRC training activities will be conducted in the same general areas, so marine mammal populations could be exposed to repeated activities over time. This does not mean, however, that there will be a repetition of any effects given the vast number of variables involved. The acoustic analyses assume that short-term non-injurious sound levels predicted to cause TTS or temporary behavioral disruptions qualify as Level B harassment from TTS. However, it is unlikely that most behavioral disruptions or instances of TTS will result in long-term significant effects. Mitigation measures reduce the likelihood of exposures to sound levels that would cause significant behavioral disruption (the higher levels of 7-9 in Figure 6-10), TTS or PTS. Based on modeling the Navy has estimated that 129,111 marine mammals per year might be exposed to activities that NMFS would consider Level B harassment under MMPA (risk function [or non-TTS] and TTS from active sonar) as a result of the Proposed Actions. The Navy does not anticipate any indirectly caused mortality to result from the Proposed Actions. It is unlikely that the short term behavioral disruption would adversely affect the species or stock through effects on annual rates of recruitment or survival.

6.6.2 Summary of Potential Mid or High-Frequency Acoustic Event Effects

Table 6-6 represents the number of sonar hours, dipping sonar, or sonobuoys usage per year from different sonar sources including the AN/SQS-53C and AN/SQS-56C surface ships sonars, the AN/AQS-22 helicopter dipping sonar, the AN/SSQ-62 DICASS sonobuoy, and the MK-48 torpedo sonar.

Table 6-6: Number of Passive and Active Sonar Events in the NWTRC.

Warfare Area	Ordnance	Number of Annual Events
Antisubmarine Warfare Tracking Exercise – Maritime Patrol Aircraft	SSQ-36 BT Sonobuoy	302
	SSQ-53 DIFAR Passive Sonobuoy	6,618
	SSQ-62 DICASS Active Sonobuoy	886
	SSQ-77 VLAD Passive Sonobuoy	412
Antisubmarine Warfare Tracking Exercise - Extended Echo Ranging (EER)	SSQ-77 Passive Sonobuoy	241
Antisubmarine Warfare Tracking Exercise - Surface Ships	Hull-mounted Mid-frequency Active Sonar	108 hours
Antisubmarine Warfare Tracking Exercise - Submarine	Hull-mounted Mid-frequency Active Sonar	0 hours
Intelligence, Surveillance, and reconnaissance (ISR).	SSQ-53 DIFAR Passive Sonobuoy	1,043

Table 6-7 presents a summary of the estimated marine mammal exposures for potential non-injurious (MMPA Level B) harassment, as well as potential onset of injury (MMPA Level A) to cetaceans and pinnipeds. It is estimated that 129,111 marine mammals will exhibit

responses NMFS will classify as behavioral harassment (MMPA Level B) as a result of MFA/HFA sonar use (128,583 using the Risk Function and 528 from TTS). One marine mammal (harbor seal) will be exposed to sonar in excess of permanent threshold shift (PTS) threshold indicative of MMPA Level A harassment.

Table 6-7: Summary of Mid-Frequency Active Sonar Exposures

Species	Level B Sonar Exposures		Level A Sonar Exposures
	Risk Function	TTS	PTS
ESA Species			
Blue whale	17	0	0
Fin whale	122	2	0
Humpback whale	13	0	0
Southern resident killer whale	13	0	0
Sei whale	1	0	0
Sperm whale	101	2	0
Steller Sea Lion	113	0	0
Sea otter	N/A	N/A	N/A
Mysticetes			
Gray whale	4	0	0
Minke whale	9	0	0
Odontocetes			
Baird's beaked whale	11	0	0
Bottlenose dolphin	0	0	0
Cuvier's beaked whale	12	0	0
Dall's porpoise	4,458	147	0
Dwarf / Pygmy sperm whale	3	0	0
Harbor porpoise*	119,103	45	0
Mesoplodon spp.	13	0	0
Northern right whale dolphin	698	18	0
Pacific white-sided dolphin	521	23	0
Risso's dolphin	85	2	0
Short beaked common dolphin	1,142	42	0
Short-finned pilot whale	2	0	0
Striped dolphin	38	1	0
Pinnipeds			
Northern elephant seal	288	0	0
Pacific harbor seal	258	245	1
California sea lion	281	0	0
Northern fur seal	1,277	1	0
Total	**128,583**	**528**	**1**

N/A: Not applicable – Based on a few historic observations, its habitat preference or overall distribution, a species may occur rarely in the NWTRC, but no density estimates were available for modeling exposures
* Threshold for MMPA Level B Harrassment is based on 120 dB step function

These exposure numbers are generated by the model without consideration of mitigation measures that would reduce the potential for marine mammal exposures to sonar. It should be noted, however, that these exposure modeling results are statistically derived estimates of potential marine mammal sonar exposures without consideration of standard mitigation and monitoring procedures. It is highly unlikely that a marine mammal would experience any long-

term effects because the large NWTRC training areas makes individual mammals' repeated or prolonged exposures to high-level sonar signals unlikely.

Specifically, mid-frequency active sonars have limited marine mammal exposure ranges and relatively high platform speeds. The number of exposures that exceed the PTS threshold and result in MMPA Level A harassment from sonar is one for the harbor seal. Therefore, long term effects on individuals, populations or stocks are unlikely.

When analyzing the results of the acoustic exposure modeling to provide an estimate of effects, it is important to understand that there are limitations to the ecological data (diving behavior, migration or movement patterns and population dynamics) used in the model, and that the model results must be interpreted within the context of a given species' ecology.

As described previously, this authorization request assumes that short-term non-injurious sound exposure levels predicted to cause TTS or temporary behavioral disruptions qualify as MMPA Level B harassment. This approach is overestimating because there is no established scientific correlation between mid-frequency active sonar use and long term abandonment or significant alteration of behavioral patterns in marine mammals.

Because of the time delay between pings, and platform speed, an animal encountering the sonar will accumulate energy for only a few sonar pings over the course of a few minutes. Therefore, exposure to sonar would be a short-term event, minimizing any single animal's exposure to sound levels approaching the harassment thresholds.

The implementation of the mitigation and monitoring procedures as addressed in Section 11 will further minimize the potential for marine mammal exposures to explosive sources. When reviewing the acoustic exposure modeling results, it is also important to understand that the estimates of marine mammal sound exposures are presented without consideration of standard protective measure operating procedures. Section 11 presents details of the mitigation measures currently used for ASW activities including detection of marine mammals and power down procedures if marine mammals are dectected within one of the safety zones. The Navy will work through the MMPA incidental harassment regulatory process to discuss the mitigation measures and their potential to reduce the likelihood for incidental harassment of marine mammals.

6.6.3 Summary of Potential Explosive Source Effects

The modeling indicates 262 annual exposures (Table 6-8) to pressure or acoustics from explosive sources that could result in a sub-TTS behavioral response (threshold of 177 dB re $1\mu Pa^2$-s) and 197 that could cause TTS (threshold of 182 dB re $1\mu Pa^2$-s or 23 psi). The total number of exposures from explosives that NMFS would classify as MMPA Level B harassment would be 471. Modeling indicates 12 exposures from explosive sources that could cause slight injury, resulting in MMPA Level A harassment and no exposures causing mortality.

Training activities involving explosives include Mine Neutralization, Air to Surface Missile Exercise, Surface to Surface Missile Exercise, Bombing Exercise, Sinking Exercise, Surface to Surface Gunnery exercise, and Naval Surface Fire Support. In a SINKEX, weapons are typically fired in order of decreasing range from the source with weapons fired until the target is sunk. Since the target may sink at any time during the exercise, the actual number of weapons used can vary widely. In the representative case, however, all of the ordnances are assumed expended; this represents the worst case of maximum exposure.

Table 6-8: Summary of Annual Exposures from Explosive Sources.

Species	Level B Explosive Exposures		Level A Exposures	Mortality
	Sub-TTS	**TTS**		
ESA Species				
Blue whale	1	1	0	0
Fin whale	12	7	1	0
Humpback whale	0	0	0	0
Southern resident killer whale	0	0	0	0
Sei whale	0	0	0	0
Sperm whale	13	10	1	0
Steller Sea Lion	3	3	0	0
Sea otter	N/A	N/A	N/A	N/A
Mysticetes				
Gray whale	0	0	0	0
Minke whale	0	0	0	0
Odontocetes				
Baird's beaked whale	1	0	0	0
Bottlenose dolphin	0	0	0	0
Cuvier's beaked whale	1	1	0	0
Dall's porpoise	62	58	3	0
Dwarf / Pygmy sperm whale	1	0	0	0
Harbor porpoise	9	5	1	0
Mesoplodon spp.	1	0	0	0
Northern right whale dolphin	11	7	1	0
Pacific white-sided dolphin	8	3	0	0
Risso's dolphin	9	4	0	0
Short beaked common dolphin	49	23	2	0
Short-finned pilot whale	0	0	0	0
Striped dolphin	0	1	0	0
Pinnipeds				
Northern elephant seal	53	29	2	0
Pacific harbor seal	2	0	0	0
California sea lion	2	1	0	0
Northern fur seal	24	44	1	0
Total	**262**	**197**	**12**	**0**

N/A: Not applicable – Based on a few historic observations, its habitat preference or overall distribution, a species may occur rarely in the NWTRC, but no density estimates were available for modeling exposures.

These exposure modeling results are estimates of marine mammal underwater detonation sound exposures without considering model limitations (Appendix A). In addition, implementation of the mitigation and monitoring procedures as addressed in Section 11 will further minimize the potential for marine mammal exposures to explosive sources.

6.7 Assessment of Marine Mammal Response to Acoustic Exposures

Section 6.1 presented the concept that potential effects of sound include both physiological effects and behavioral effects. Section 6.2 also provides information on how physiological

effects and behavioral responses are considered in development of acoustic modeling. Acoustic exposures are evaluated based on their potential direct effects on marine mammals, and these effects are then assessed in the context of the species biology and ecology to determine if there is a mode of action that may result in the acoustic exposure warranting consideration as a harassment level effect. A large body of research on terrestrial animal and human response to airborne sound exists, but results from those studies are not readily extendible to the development of effect criteria and thresholds for marine mammals. For example, "annoyance" is one of several criteria used to define impact to humans from exposure to industrial sound sources. Comparable criteria cannot be developed for marine mammals because there is no acceptable method for determining whether a non-verbal animal is annoyed. Further, differences in hearing thresholds, dynamic range of the ear, and the typical exposure patterns of interest (e.g., human data tend to focus on 8-hour-long exposures) make extrapolation of human sound exposure standards inappropriate. Behavioral observations of marine mammals exposed to anthropogenic sound sources exist, however, there are few observations and no controlled measurements of behavioral disruption of cetaceans caused by sound sources with frequencies, waveforms, durations, and repetition rates comparable to those employed by the tactical sonars to be used in the NWTRC. At the present time there is no consensus on how to account for behavioral effects on marine mammals exposed to continuous-type sounds (NRC 2003).

This application uses behavioral observations of trained cetaceans exposed to intense underwater sound under controlled circumstances to develop a criterion and threshold for behavioral effects of sound as discussed previously. These data, because they are based on controlled, tonal sound exposures within the tactical sonar frequency range, are the most applicable. When analyzing the results of the acoustic effect modeling to provide an estimate of harassment, it is important to understand that there are limitations to the ecological data used in the model, and to interpret the model results within the context of a given species' ecology.

Limitations in the model include:

- Density estimates (May be limited in duration and time of year and are modeled to derive density estimates).

- When reviewing the acoustic effect modeling results, it is also important to understand that the estimates of marine mammal sound exposures are presented without consideration of mitigation which may reduce the potential for estimated sound exposures to occur.

6.7.1.1 Potential Injury

As described previously, with respect to the acoustic model, the model inputs included the lowest sound level at which a response might occur. For example, the model considered the potential of onset of PTS in estimating exposures that might result in permanent tissue damage. Other effects postulated as permanent damage to marine mammal tissues also are considered in evaluating the potential for the estimated acoustic exposures to actually result in tissue damage. Resonance, rectified diffusion and decompression sickness were describe above the arguments for and against were presented with the conclusion that these effects are unlikely to occur.

6.7.1.2 Behavioral Disturbance

TTS used as an onset of physiological response but not at the level of injury. This response is easily measured in a laboratory situation but is difficult to predict in free ranging animals expose

to sound. Because it is an involuntary response, it is easier to predict than behavioral responses. The risk function methodology considers other exposures which may include a variety of modes of action that could result in behavioral responses.

Limited information from literature on the proximal responses specific to mid-frequency active sonar and marine mammals require the use of information from other species and from other types of acoustic sources to build a conceptual model for considering issues such as allostatic loading, spatial disorientation, impaired navigation and disrupted life history events, disrupted communication, or increased energy costs. The risk function methodology assumes a range of responses from very low levels of exposure for certain individuals (with some individuals being more reactive then others depending on the situation – i.e., foraging, breeding, migrating), with increasing probability of response as the received sound level increases. The result is estimate of probability that the range of physiological and behavioral responses that might occur are accounted for in determining the number of harassment incidents. The predicted responses using the risk function and TTS methodology are conservatively estimated to result in the disruption of natural behavioral patterns although it is assumed that such behavioral patterns are not abandoned or significantly altered.

6.7.1.3 No Harassment

Although a marine mammal may be exposed to mid-frequency active sonar, it may not respond or may only show a mild response, which may not rise to the level of harassment. In using the risk function it is assumed that the response of animals is variable, depending on their activity, gender or age, and that higher sound levels are more likely to elicit a greater response. Each exposure, using the Risk Function methodology, represents the probability of a response that NMFS would classify as harassment under the MMPA. The ESA listed species that may be exposed to mid-frequency active sonar in the NWTRC include the blue whale, fin whale, humpback whale, sei whale, and sperm whale. The exposure modeling was completed using the same methodology as that for non-ESA listed species. A different analytical framework will be used to discuss potential exposure and affects to ESA-listed species because the ESA consultation process is interested in population level effects (severely depleted or endangered populations) rather than stocks or species effects.

6.7.1.4 Marine Mammals

The best scientific information on the status, abundance and distribution, behavior and ecology, diving behavior and acoustic abilities are provided for each species expected to be found within the NWTRC (Sections 3 and 4). Information was reviewed on the response of marine mammals to other sound sources such as seismic air guns or ships but these sources tend to be longer in the period of exposure or continuous in nature. The response of marine mammals to those sounds, and mid-frequency active sonar, are variable with some animals showing no response or moving toward the sound source while others may move away (Review by Richardson et al. 1995; Andre et al. 1997; Nowacek et al. 2004). The analytical framework shows the range of physiological and behavioral responses that can occur when an animal is exposed to an acoustic source. Physiological effects include auditory trauma (TTS, PTS, and tympanic membrane rupture), stress or changes in health and bubble formation or decompression sickness. Behavioral responses may occur due to stress in response to the sound exposure. Behavioral responses may include flight response, changes in diving, foraging or reproductive behavior, changes in vocalizations (may cease or increase intensity), changes in migration or movement patterns or

the use of certain habitats. Whether an animal responds, the types of behavioral changes, and the magnitude of those changes may depend on the intensity level of the exposure and the individual animal's prior status or behavior. Little information is available to determine the response of animals to mid-frequency active sonar and its effects on ultimate and proximate life functions or at the population or species level.

6.7.2 Estimated Effects on ESA Species

The endangered species that may be affected as a result of implementation of the NWTRC activities include the blue whale, fin whale, humpback whale, North Pacific right whale, sei whale, and sperm whale.

6.7.2.1 Blue Whale

The risk function and Navy post-modeling analysis estimates 17 blue whales will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be zero exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No blue whales would be exposed to sound levels that could cause PTS.

Modeling indicates there would one exposure to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would one exposure to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given the large size (up to 98 ft [30 m]) of individual blue whales (Leatherwood et al. 1982), pronounced vertical blow, and aggregation of approximately two to three animals in a group (probability of track line detection = 0.90 in Beaufort Sea States of 6 or less; Barlow 2003), it is very likely that lookouts would detect a group of blue whales at the surface. Additionally, mitigation measures call for continuous visual observation during activities with active sonar; therefore, blue whales that migrate into the operating area would be detected by visual observers. Implementation of mitigation measures and probability of detecting a large blue whale reduces the likelihood of exposure, such that effects would be discountable.

In the unlikely event that blue whales are exposed to mid-frequency sonar, the anatomical information available on blue whales suggests that they are not likely to hear mid-frequency (1 kHz–10 kHz) sounds (Ketten 1997). There are no audiograms of baleen whales, but blue whales tend to react to anthropogenic sound below 1 kHz (e.g., seismic air guns), and most of their vocalizations are also in that range, suggesting that they are more sensitive to low frequency sounds (Richardson *et al*. 1995). Based on this information, if they do no hear these sounds, they are not likely to respond physiologically or behaviorally to those received levels.

Based on the model results, behavioral patterns, acoustic abilities of blue whales, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not likely result in any death or injury to blue whales. Modeling does indicate the potential for MMPA Level B harassment, indicating the proposed ASW exercises may affect blue whales. An ESA consultation is ongoing, and includes the finding that the proposed ASW exercises **may affect blue whales**. Should consultation under the ESA conclude that the estimated exposures of humpback whales can be avoided via

mitigation measures or that the received sound is not likely to adversely affect blue whales, authorization for the predicted exposures would not be requested under MMPA. At this time, this application requests authorization for the annual harassment of 19 blue whales by MMPA Level B harassment (17 from mid-frequency active sonar and two from explosive sources) and one blue whale by MMPA Level A harassment from potential exposure to mid-frequency active sonar.

6.7.2.2 Fin Whale

The risk function and Navy post-modeling analysis estimates 122 fin whales will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be two exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No fin whales would be exposed to sound levels that could cause PTS.

Modeling indicates there would 12 exposure to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would be seven exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and one exposure to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given the large size (up to 78 ft [24m]) of individual fin whales (Leatherwood et al. 1982), pronounced vertical blow, mean aggregation of three animals in a group (probability of trackline detection = 0.90 in Beaufort Sea States of 6 or less; Barlow 2003) it is very likely that lookouts would detect a group of fin whales at the surface. Additionally, mitigation measures call for continuous visual observation during activities with active sonar, therefore, fin whales in the vicinity of activities would be detected by visual observers. Implementation of mitigation measures and probability of detecting a large fin whale reduces the likelihood of exposure, such that effects would be discountable.

In the unlikely event that fin whales are exposed to mid-frequency sonar, the anatomical information available on fin whales suggests that they are not likely to hear mid-frequency (1 kHz–10 kHz) sounds (Richardson et al. 1995; Ketten 1997). Fin whales primarily produce low frequency calls (below 1 kHz) with source levels up to 186 dB re 1μPa at 1 m, although it is possible they produce some sounds in the range of 1.5 to 28 kHz (review by Richardson et al. 1995; Croll et al. 2002). There are no audiograms of baleen whales, but they tend to react to anthropogenic sound below 1 kHz, suggesting that they are more sensitive to low frequency sounds (Richardson et al. 1995). Based on this information, if they do no hear these sounds, they are not likely to respond physiologically or behaviorally to those received levels.

In the St. Lawrence estuary area, fin whales avoided vessels with small changes in travel direction, speed and dive duration, and slow approaches by boats usually caused little response (MacFarlane 1981). Fin whales continued to vocalize in the presence of boat sound (Edds and Macfarlane 1987). Even though any undetected fin whales transiting the NWTRC may exhibit a reaction when initially exposed to active acoustic energy, field observations indicate the effects would not cause disruption of natural behavioral patterns to a point where such behavioral patterns would be abandoned or significantly altered.

Based on the model results, behavioral patterns, acoustic abilities of fin whales, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not likely result in any death or injury to fin whales. Modeling does indicate the potential for MMPA Level B harassment, indicating the proposed ASW exercises may affect fin whales. An ESA consultation is ongoing, and includes the finding that the proposed ASW exercises **may affect fin whales**. Should consultation under the ESA conclude that the estimated exposures of humpback whales can be avoided via mitigation measures or that the received sound is not likely to adversely affect fin whales, authorization for the predicted exposures would not be requested under MMPA. At this time, this application requests authorization for the annual harassment of 143 fin whales by MMPA Level B harassment (124 from mid-frequency active sonar and 19 from explosive sources), and one fin whale by MMPA Level A harassment from potential exposure to underwater detonation.

6.7.2.3 Humpback Whale

The risk function and Navy post-modeling analysis estimates 13 humpback whales will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be no exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No humpback whales would be exposed to sound levels that could cause PTS.

Modeling indicates there would no exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would zero exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given the large size (up to 53 ft [16m] of individual humpback whales (Leatherwood et al. 1982), and pronounced vertical blow, it is very likely that lookouts would detect humpback whales at the surface. Additionally, mitigation measures call for continuous visual observation during activities with active sonar, therefore, humpback whales that are present in the vicinity of ASW activities would be detected by visual observers reducing the likelihood of exposure, such that effects would be discountable.

There are no audiograms of baleen whales, but they tend to react to anthropogenic sound below 1 kHz, suggesting that they are more sensitive to low frequency sounds (Richardson et al. 1995). A single study suggested that humpback whales responded to mid-frequency sonar (3.1-3.6 kHz re 1 μPa^2-s) sound (Maybaum 1989). The hand held sonar system had a sound artifact below 1,000 Hz which caused a response to the control playback (a blank tape) and may have affected the response to sonar (i.e., the humpback whale responded to the low frequency artifact rather than the mid-frequency active sonar sound). Humpback whales responded to small vessels (often whale watching boats) by changing swim speed, respiratory rates and social interactions depending on proximity to the vessel and vessel speed, with reponses varying by social status and gender (Watkins et al. 1981; Bauer 1986; Bauer and Herman 1986). Animals may even move out of the area in response to vessel noise (Salden 1988). Humpback whale mother-calf pairs are generally in the shallow protected waters. ASW mid-frequency active sonar activities takes place through out the extensive NWTRC but the areas inhabited by humpback whales is represents only a small portion of the NWTRC. Frankel and Clark (2000; 2002) reported that

there was only a minor response by humpback whales to the Acoustic Thermometry of Ocean Climate (ATOC) sound source and that response was variable with some animals being found closer to the sound source during operation.

Based on the model results, behavioral patterns, acoustic abilities of humpback whales, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not likely result in any death or injury to humpback whales. Modeling does indicate the potential for MMPA Level B harassment, indicating the proposed ASW exercises may affect humpback whales. An ESA consultation is ongoing, and includes the finding that the proposed ASW exercises **may affect humpback whales**. Should consultation under the ESA conclude that the estimated exposures of humpback whales can be avoided via mitigation measures or that the received sound is not likely to adversely affect humpback whales, authorization for the predicted exposures would not be requested under MMPA. At this time, this application requests authorization for the annual harassment of 13 humpback whales by MMPA Level B harassment (13 from mid-frequency active sonar and 0 from explosive sources) and no humpback whales by MMPA Level A harassment from potential exposure to mid-frequency active sonar or explosive sources.

6.7.2.4 Sei Whale

The risk function and Navy post-modeling analysis estimates one sei whale will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be zero exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No sei whales would be exposed to sound levels that could cause PTS.

Modeling indicates there would no exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would zero exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given the large size (up to 53 ft [16m]) of individual sei whales (Leatherwood et al. 1982), pronounced vertical blow, aggregation of approximately three animals (probability of trackline detection = 0.90 in Beaufort Sea States of 6 or less; Barlow 2003), it is very likely that lookouts would detect a group of sei whales at the surface. Additionally, mitigation measures call for continuous visual observation during activities with active sonar, therefore, sei whales that migrate into the operating area would be detected by visual observers. Implementation of mitigation measures and probability of detecting a large sei whale reduces the likelihood of exposure, such that effects would be discountable.

There is little information on the acoustic abilities of sei whales or their response to human activities. The only recorded sounds of sei whales are frequency modulated sweeps in the range of 1.5 to 3.5 kHz (Thompson et al. 1979) but it is likely that they also vocalized at frequencies below 1 kHz as do fin whales. There are no audiograms of baleen whales but they tend to react to anthropogenic sound below 1 kHz suggesting that they are more sensitive to low frequency sounds (Richardson et al. 1995). Sei whales were more difficult to approach than were fin whales and moved away from boats but were less responsive when feeding (Gunther 1949).

Based on the model results, behavioral patterns, acoustic abilities of sei whales, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not likely result in any death or injury to sei whales. Modeling does indicate the potential for MMPA Level B harassment, indicating the proposed ASW exercises **may affect sei whales**. An ESA consultation is ongoing, and includes the finding that the proposed ASW exercises may affect sei whales. Should consultation under the ESA conclude that the estimated exposures of sei whales can be avoided via mitigation measures or that the received sound is not likely to adversely affect sei whales, authorization for the predicted exposures would not be requested under MMPA. At this time, this application requests authorization for the annual harassment of one sei whale by MMPA Level B harassment and no sei whales by MMPA Level A harassment from potential exposure to mid-frequency active sonar or explosive sources.

6.7.2.5 Sperm Whales

The risk function and Navy post-modeling analysis estimates 101 sperm whales will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be two exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No sperm whale would be exposed to sound levels that could cause PTS.

Modeling indicates there would 13 exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would ten exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and one exposure to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given the large size (up to 56 ft [17m]) of individual sperm whales (Leatherwood et al. 1982), pronounced blow (large and angled), mean group size of approximately seven animals (probability of trackline detection = 0.87 in Beaufort Sea States of 6 or less; Barlow 2003; 2006), it is very likely that lookouts would detect a group of sperm whales at the surface. Sperm whales can make prolonged dives of up to two hours (Watwood et al. 2006) making detection more difficult. Additionally, mitigation measures call for continuous visual observation during activities with active sonar; therefore, sperm whales that migrate into the operating area would be detected by visual observers. Implementation of mitigation measures and probability of detecting a large sperm whale reduces the likelihood of exposure, such that effects would be discountable.

In the unlikely event that sperm whales are exposed to mid-frequency sonar, the information available on sperm whales exposed to received levels of active mid-frequency sonar suggests that the response to mid-frequency (1 kHz to 10 kHz) sounds is variable (Richardson et al. 1995). While Watkins et al. (1985) observed that sperm whales exposed to 3.25 kHz to 8.4 kHz pulses interrupted their activities and left the area, other studies indicate that, after an initial disturbance, the animals return to their previous activity. During playback experiments off the Canary Islands, André et al. (1997) reported that foraging whales exposed to a 10 kHz pulsed signal did not exhibit any general avoidance reactions. When resting at the surface in a compact group, sperm whales initially reacted strongly but then ignored the signal completely (André et al. 1997).

Based on the model results, behavioral patterns, acoustic abilities of sperm whales, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not likely result in any death or injury to sperm whales. Modeling does indicate the potential for MMPA Level B harassment, indicating the proposed ASW exercises **may affect sperm whales**. An ESA consultation is ongoing, and includes the finding that the proposed ASW exercises may affect sperm whales. Should consultation under the ESA conclude that the estimated exposures of sperm whales can be avoided via mitigation measures or that the received sound is not likely to adversely affect sperm whales, authorization for the predicted exposures would not be requested under MMPA. At this time, this application requests authorization for the annual harassment of 126 sperm whales by MMPA Level B harassment (103 from mid-frequency active sonar and 23 from explosive sources) and one sperm whale by MMPA Level A harassment from potential exposure to explosive sources.

6.7.2.6 Southern Resident Killer Whales

Due to the difficulty in determining particular stocks of killer whales in the wild, all stocks of killer whales were combined for modeling exposures. While overly conservative, all killer whales were assumed to belong to the southern resident killer whale stock. The risk function and Navy post-modeling analysis estimates 13 killer whales will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be no exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No killer whales would be exposed to sound levels that could cause PTS.

Modeling indicates there would no exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would zero exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given their size (up to 23 ft [7.0 m]), conspicuous coloring, pronounce dorsal fin and large mean group size of 6.5 animals (probability of trackline detection = 0.90 in Beaufort Sea States of 6 or less; Barlow, 2003). It is very likely that lookouts would detect a group of killer whales at the surface. Additionally, mitigation measures call for continuous visual observation during activities with active sonar, therefore, killer whales that migrate into the operating area would be detected by visual observers. Implementation of mitigation measures and probability of detecting large groups of killer whales reduces the likelihood of exposure.

Based on the model results, behavioral patterns, acoustic abilities of killer whales, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to killer whales. Modeling does indicate the potential for MMPA Level B harassment, indicating the proposed ASW exercises **may affect killer whales**. At this time, this application requests authorization for the annual harassment of 12 killer whales by MMPA Level B harassment (13 from mid-frequency active sonar and zero from explosive sources) and no killer whales by MMPA Level A harassment from potential exposure to mid-frequency active sonar or underwater detonation.

6.7.2.7 Steller Sea Lion

The risk function and Navy post-modeling analysis estimates 113 Steller sea lions will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be no exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No Steller sea lions would be exposed to sound levels that could cause PTS.

Modeling indicates there would three exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would three exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and no exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Based on the model results, behavioral patterns, acoustic abilities of Steller sea lions, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not likely result in any death or injury to Steller sea lions. Modeling does indicate the potential for MMPA Level B harassment, indicating the proposed ASW exercises **may affect Steller sea lions**. An ESA consultation is ongoing, and includes the finding that the proposed ASW exercises may affect Steller sea lions. Should consultation under the ESA conclude that the estimated exposures of Steller sea lions can be avoided via mitigation measures or that the received sound is not likely to adversely affect Steller sea lions, authorization for the predicted exposures would not be requested under MMPA. At this time, this application requests authorization for the annual harassment of 119 Steller sea lions by MMPA Level B harassment (113 from mid-frequency active sonar and six from explosive sources) only.

6.7.3 Estimated Exposures for Non-ESA Species

6.7.3.1 Gray Whale

The risk function and Navy post-modeling analysis estimates four gray whales will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be zero exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No gray whales would be exposed to sound levels that could cause PTS.

Modeling indicates there would no exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would zero exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given the large size (up to 46 ft. [14 m]) of individual gray whales, pronounced blow, and group size of up to 16 animals (Leatherwood et al. 1982) and (probability of trackline detection = 0.87 in Beaufort Sea States of 6 or less; Barlow 2003; 2006), it is very likely that lookouts would detect a group of gray whales at the surface. Additionally, mitigation measures call for continuous visual observation during activities with active sonar, therefore, gray whales that migrate into the operating area would be detected by visual observers. Implementation of

mitigation measures and probability of detecting a gray whale reduces the likelihood of exposure, such that effects would be discountable.

Based on the model results, behavioral patterns, acoustic abilities of gray whales, results of past training, and the implementation of procedure protective measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to gray whales. At this time, this application requests authorization for the annual harassment of four gray whales by MMPA Level B harassment from mid-frequency active sonar only.

6.7.3.2 Minke Whale

The risk function and Navy post-modeling analysis estimates nine minke whales will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be no exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No minke whales would be exposed to sound levels that could cause PTS.

Modeling indicates there would no exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would zero exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Minke whales are difficult to spot visually but can be detected using passive acoustic monitoring. Additionally, mitigation measures call for continuous visual observation during activities with active sonar, therefore, minke whales that migrate into the operating area would be detected by visual observers. Implementation of mitigation measures and probability of detecting a minke whale reduces the likelihood of exposure, such that effects would be discountable.

Based on the model results, behavioral patterns, acoustic abilities of minke whales, results of past training, and the implementation of procedure protective measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to minke whales. At this time, this application requests authorization for the annual harassment of nine minke whales by MMPA Level B harassment from mid-frequency active sonar only.

6.7.3.3 Baird's Beaked Whale

The risk function and Navy post-modeling analysis estimates 11 Baird's beaked whales will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be no exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No Baird's beaked whales would be exposed to sound levels that could cause PTS.

Modeling indicates there would one exposure to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would zero exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given the size (up to 15.5 ft. [4.7 m]) of individual Baird's beaked whales, aggregation of 2.3 animals, it is likely that lookouts would detect a group of Baird's beaked whales at the surface although beaked whales make prolonged dives that can last up to an hour (Baird et al. 2004). Implementation of mitigation measures and probability of detecting a large sei whale reduces the likelihood of exposure, such that effects would be discountable.

Based on the model results, behavioral patterns, acoustic abilities of Baird's beaked whales, results of past training, and the implementation of procedure protective measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to Baird's beaked whales. At this time, this application requests authorization for the annual harassment of 12 Baird's beaked whales by MMPA Level B harassment (11 from mid-frequency active sonar and one from explosive sources) only.

6.7.3.4 Bottlenose Dolphin

The risk function and Navy post-modeling analysis estimates no bottlenose dolphins will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be zero exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No bottlenose dolphins would be exposed to sound levels that could cause PTS.

Modeling indicates there would no exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would zero exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given the frequent surfacing, aggregation of approximately 9 animals (probability of trackline detection = 0.76 in Beaufort Sea States of 6 or less; Barlow 2003), it is very likely that lookouts would detect a group of bottlenose dolphins at the surface. Additionally, mitigation measures call for continuous visual observation during activities with active sonar, therefore, bottlenose dolphins that migrate into the operating area would be detected by visual observers. Implementation of mitigation measures and probability of detecting bottlenose dolphins reduces the likelihood of exposure, such that effects would be discountable.

Based on the model results, behavioral patterns, acoustic abilities of bottlenose dolphins, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to bottlenose dolphins. At this time, this application does not request authorization for the annual harassment bottlenose dolphins by MMPA Level B or MMPA Level A harassment from potential exposure to mid-frequency active sonar or explosive sources.

6.7.3.5 Cuvier's Beaked Whale

The risk function and Navy post-modeling analysis estimates 12 Cuvier's beaked whales will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be zero exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No Cuvier's beaked whale would be exposed to sound levels that could cause PTS.

Modeling indicates there would one exposure to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would one exposure to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given the medium size (up to 23 ft. [7.0 m]) of individual Cuvier's beaked whales, aggregation of approximately two animals (Barlow 2006), it is likely that lookouts would detect a group of Cuvier's beaked whales at the surface although beaked whales make prolonged dives that can last up to an hour (Baird et al. 2004). Implementation of mitigation measures and probability of detecting a large sei whale reduces the likelihood of exposure, such that effects would be discountable.

Based on the model results, behavioral patterns, acoustic abilities of Cuvier's beaked whales, results of past training, and the implementation of procedure protective measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to Cuvier's beaked whales. At this time, this application requests authorization for the annual harassment of 14 Cuvier's beaked whales by MMPA Level B harassment (12 from mid-frequency active sonar and two from explosive sources) only.

6.7.3.6 Dall's Porpoise

The risk function and Navy post-modeling analysis estimates 4,458 Dall's porpoises will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 147 exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No Dall's porpoises would be exposed to sound levels that could cause PTS.

Modeling indicates there would 62 exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would 58 exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and three exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given the frequent surfacing and aggregation of approximately 2-20 animals, it is very likely that lookouts would detect a group of Dall's porpoises at the surface. Additionally, protective measures call for continuous visual observation during activities with active sonar, therefore, Dall's porpoises that migrate into the operating area would be detected by visual observers. Implementation of mitigation measures and probability of detecting large groups of Dall's porpoises reduces the likelihood of exposure.

Based on the model results, behavioral patterns, acoustic abilities of Dall's porpoise, results of past training, and the implementation of procedure protective measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects to Dall's porpoise. At this time, this application requests authorization for the annual harassment of 4,725 Dall's porpoise by MMPA Level B harassment (4,605 from mid-frequency active sonar and 120 from explosive sources) and three Dall's porpoise by MMPA Level A harassment from potential exposure to explosive sources.

6.7.3.7 Dwarf or Pygmy Sperm Whale

The risk function and Navy post-modeling analysis estimates three dwarf or pygmy sperm whales will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be no exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No dwarf or pygmy sperm whales would be exposed to sound levels that could cause PTS.

Modeling indicates there would be one exposure to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would zero exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given their size (up to 10 ft [3 m]) and behavior of resting at the surface (Leatherwood et al. 1982), it is very likely that lookouts would detect a dwarf or pygmy sperm whale at the surface. Additionally, mitigation measures call for continuous visual observation during activities with active sonar and explosive sources, therefore, dwarf or pygmy sperm whales that migrate into the operating area would be detected by visual observers. Implementation of mitigation measures and probability of detecting large groups of dwarf or pygmy sperm whales reduces the likelihood of exposure.

Based on the model results, behavioral patterns, acoustic abilities of dwarf or pygmy sperm whales, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to dwarf or pygmy sperm whale. At this time, this application requests authorization for the annual harassment of four pygmy sperm whales by MMPA Level B harassment (three from mid-frequency active sonar and one from explosive sources) only.

6.7.3.8 Harbor Porpoise

The 120 dB step function and Navy post-modeling analysis estimates 119,103 harbor porpoises will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 45 exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No harbor porpoises would be exposed to sound levels that could cause PTS.

Modeling indicates there would nine exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would five exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and one exposure to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given the frequent surfacing with characteristic rooster tail and aggregation of approximately 2-20 animals, it is very likely that lookouts would detect a group of harbor porpoises at the surface (Leatherwood et al., 1982). Additionally, mitigation measures call for continuous visual observation during activities with active sonar and explosive sources, therefore, harbor porpoises that migrate into the operating area would be detected by visual observers. Implementation of

ROP and probability of detecting large groups of harbor porpoises reduces the likelihood of exposure.

Based on the model results, behavioral patterns, acoustic abilities of harbor porpoises, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to harbor porpoises. At this time, this application requests authorization for the annual harassment of 119,162 harbor porpoises by MMPA Level B harassment (119,148 from mid-frequency active sonar and 14 from explosive sources) and one harbor porpoise by MMPA Level A harassment from potential exposure to explosive sources.

6.7.3.9 Mesoplodont Whales

The risk function and Navy post-modeling analysis estimates 13 Mesoplodont whales will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be zero exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No Mesoplodont whales would be exposed to sound levels that could cause PTS.

Modeling indicates there would be one exposure to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would zero exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given the size (up to 15.5 ft. [4.7 m]) of individual Mesoplodont beaked whales, it is likely that lookouts would detect a group of Mesoplodont beaked whales at the surface although beaked whales make prolonged dives that can last up to an hour (Baird et al. 2004). Implementation of mitigation measures and probability of detecting a Mesoplodont whale reduces the likelihood of exposure, such that effects would be discountable.

Based on the model results, behavioral patterns, acoustic abilities of Mesoplodont beaked whales, results of past training, and the implementation of procedure protective measures presented in Section 11 for explosive sources, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to Mesoplodont beaked whales. At this time, this application requests authorization for the annual harassment of 14 Mesoplodont whales by MMPA Level B harassment (13 from mid-frequency active sonar and one from explosive sources) and zero Mesoplodont whales by MMPA Level A harassment from potential exposure to mid-frequency active sonar or explosive sources.

6.7.3.10 Northern Right Whale Dolphin

The risk function and Navy post-modeling analysis estimates 698 northern right whale dolphins will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 18 exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No northern right whale dolphins would be exposed to sound levels that could cause PTS.

Modeling indicates there would be 11 exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would seven exposures to impulsive sound or pressures from

explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and one exposure to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given their large group size of up to 100 animals (Leatherwood et al. 1982), it is very likely, that lookouts would detect a group of northern right whale dolphins at the surface. Additionally, mitigation measures call for continuous visual observation during activities with active sonar and explosive sources, therefore, northern right whale dolphins that migrate into the operating area would be detected by visual observers. Implementation of protective measures and probability of detecting large groups of northern right whale dolphins reduces the likelihood of exposure.

Based on the model results, behavioral patterns, acoustic abilities of northern right whale dolphins, results of past training, and the implementation of procedure protective measures presented in Section 11 for explosive sources, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to northern right whale dolphins. At this time, this application requests authorization for the annual harassment of 734 northern right whale dolphins by MMPA Level B harassment (716 from mid-frequency active sonar and 18 from explosive sources) and one northern right whale dolphin by MMPA Level A harassment from potential exposure to explosive sources.

6.7.3.11 Pacific White-sided Dolphin

The risk function and Navy post-modeling analysis estimates 521 Pacific white-sided dolphin will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 23 exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No Pacific white-sided dolphins would be exposed to sound levels that could cause PTS.

Modeling indicates there would be eight exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would three exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given their frequent surfacing and large group size of up to several thousand animals (Leatherwood et al. 1982), it is very likely that lookouts would detect a group of Pacific white-sided dolphins at the surface. Additionally, protective measures call for continuous visual observation during activities with active sonar and explosive sources, therefore, Pacific white-sided dolphins that migrate into the operating area would be detected by visual observers. Implementation of mitigation measures and probability of detecting large groups of Pacific white-sided dolphins reduces the likelihood of exposure.

Based on the model results, behavioral patterns, acoustic abilities of Pacific white-sided dolphins, results of past training, and the implementation of procedure protective measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to Pacific white-sided dolphins. At this time, this application requests authorization for the annual harassment of 555 Pacific white-sided dolphins by MMPA Level B harassment (544 from mid-frequency active sonar and 11 from explosive sources) only.

6.7.3.12 Risso's Dolphin

The risk function and Navy post-modeling analysis estimates 85 Risso's dolphins will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be two exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No Risso's dolphins would be exposed to sound levels that could cause PTS.

Modeling indicates there would be nine exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would four exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given their frequent surfacing, light coloration and large group size of up to several hundred animals (Leatherwood et al. 1982), probability of trackline detection of 0.76 in Beaufort Sea States of 6 or less (Barlow 2006), it is very likely that lookouts would detect a group of Risso's dolphins at the surface. Additionally, mitigation measures call for continuous visual observation during activities with active sonar and explosive sources, therefore, Risso's dolphins that migrate into the operating area would be detected by visual observers. Implementation of mitigation measures and probability of detecting large groups of Risso's dolphins reduces the likelihood of exposure.

Based on the model results, behavioral patterns, acoustic abilities of Risso's dolphins, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to Risso's dolphins. At this time, this application requests authorization for the annual harassment of 100 Risso's dolphins by MMPA Level B harassment (87 from mid-frequency active sonar and 13 from explosive sources).

6.7.3.13 Short-Beaked Common Dolphin

The risk function and Navy post-modeling analysis estimates 1,142 short-beaked common dolphins will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 42 exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No short-beaked common dolphins would be exposed to sound levels that could cause PTS.

Modeling indicates there would be 49 exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would 23 exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and two exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given the frequent surfacing and their large group size of up to 1,000 animals (Leatherwood et al. 1982), it is very likely, that lookouts would detect a group of short-beaked common dolphins at the surface. Additionally, mitigation measures call for continuous visual observation during activities with active sonar and explosive sources, therefore, common dolphins that migrate into the operating area would be detected by visual observers. Exposure of short-beaked common

dolphins to energy levels associated with MMPA Level A harassment would not occur because mitigation measures would be implemented, large groups of short-beaked common dolphins would be observed, and explosive sources result in a small zone of influence.

Based on the model results, behavioral patterns, acoustic abilities of short-beaked common dolphins, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to short-beaked common dolphins. At this time, this application requests authorization for the annual harassment of 1,256 short-beaked common dolphins by MMPA Level B harassment (1,184 from mid-frequency active sonar and 72 from explosive sources), and two short-beaked common dolphins by MMPA Level A harassment from underwater detonations).

6.7.3.14 Short-finned Pilot Whale

The risk function and Navy post-modeling analysis estimates two short-finned pilot whales will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be zero exposures to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No short-finned pilot whale would be exposed to sound levels that could cause PTS.

Modeling indicates there would be no exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would zero exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given their size (up to 20 ft [6.1 m]), and large mean group size of 22.5 animals (probability of trackline detection = 0.76 in Beaufort Sea States of 6 or less; Barlow 2006). It is very likely that lookouts would detect a group of short-finned pilot whales at the surface. Additionally, mitigation measures call for continuous visual observation during activities with active sonar, therefore, short-finned pilot whales that migrate into the operating area would be detected by visual observers. Implementation of mitigation measures and probability of detecting groups of short-finned pilot whales reduces the likelihood of exposure.

Based on the model results, behavioral patterns, acoustic abilities of short-finned pilot whale, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to short-finned pilot whale. At this time, this application requests authorization for the annual harassment of two short-finned pilot whales by MMPA Level B harassment from mid-frequency active sonar.

6.7.3.15 Striped Dolphin

The risk function and Navy post-modeling analysis estimates 38 striped dolphins will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be one exposure to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No striped dolphins would be exposed to sound levels that could cause PTS.

Modeling indicates there would be no exposure to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would one exposure to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Given their frequent surfacing, aerobatics and large mean group size of 37.3 animals (probability of trackline detection = 1.00 in Beaufort Sea States of 6 or less; Barlow 2006), it is very likely that lookouts would detect a group of striped dolphins at the surface. Additionally, mitigation measures call for continuous visual observation during activities with active sonar, therefore, striped dolphins that migrate into the operating area would be detected by visual observers. Implementation of mitigation measures and probability of detecting groups of striped dolphins reduces the likelihood of exposure.

Based on the model results, behavioral patterns, acoustic abilities of striped dolphins, results of past training, and the implementation of procedure mitigation measures presented in Section 11 for explosive sources, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to striped dolphins. At this time, this application requests authorization for the annual harassment of 40 striped dolphins by MMPA Level B harassment (39 from mid-frequency active sonar and one from explosive sources).

6.7.3.16 Northern Elephant Seal

The risk function and Navy post-modeling analysis estimates 288 northern elephant seals will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be no exposures to accumulated acoustic energy above 204 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS for northern elephant seals. No northern elephant seals would be exposed to sound levels that could cause PTS.

Modeling indicates there would be 53 exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would 29 exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and two exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Northern elephant seals tend to dive for long periods, 20-30 minutes, and only spend about 10% of the time at the surface making them difficult to detect. Elephant seals migrate out of the southern California area to forage for several months at a time (Le Boeuf 1994).

Based on the model results, behavioral patterns, acoustic abilities of Northern elephant seals, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to Northern elephant seals. At this time, this application requests authorization for the annual harassment of 370 northern elephant seals by MMPA Level B harassment (288 from mid-frequency active sonar and 82 from explosive sources) and two northern elephant seals by MMPA Level A harassment from potential exposure to explosive sources.

6.7.3.17 Pacific Harbor Seal

The risk function and Navy post-modeling analysis estimates 258 Pacific harbor seals will exhibit behavioral responses to sonar NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 245 exposures to accumulated acoustic energy above 183 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS for Pacific harbor seals. One Pacific harbor seal would be exposed to sound levels that could cause PTS.

Modeling indicates there would be two exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would zero exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Harbor seals forage near their rookeries (usually within 50 km) therefore they tend to remain in the southern California area most of the time in comparison to northern elephant seals.

Based on the model results, behavioral patterns, acoustic abilities of harbor seals, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to harbor seals. At this time, this application requests authorization for the annual harassment of 505 Pacific harbor seals by MMPA Level B harassment (503 from mid-frequency active sonar and two from explosive sources) and one Pacific harbor seal by MMPA Level A harassment from mid-frequency active sonar.

6.7.3.18 California Sea Lion

The risk function and Navy post-modeling analysis estimates 281 California sea lions will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be no exposures to accumulated acoustic energy above 206 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS for California sea lions. No California sea lions would be exposed to sound levels that could cause PTS.

Modeling indicates there would be two exposures to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would one exposure to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and zero exposures to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

California sea lions make short duration dives and may rest at the surface (Feldkamp et al. 1989) making them easier to detect than other pinnipeds.

Based on the model results, behavioral patterns, acoustic abilities of California sea lions, results of past training, and the implementation of procedure mitigation measures presented in Sections 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to harbor seals. At this time, this application requests authorization for the annual harassment of 284 California sea lions by MMPA Level B harassment (281 from mid-frequency active sonar and three from explosive sources) only.

6.7.3.19 Northern Fur Seal

The risk function and Navy post-modeling analysis estimates 1,277 northern fur seals will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be one exposure to accumulated acoustic energy above 195 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. No northern fur seals would be exposed to sound levels that could cause PTS.

Modeling indicates there would be 24 exposure to impulsive sound or pressures from explosive sources of 177 dB, which is the threshold indicative of sub-TTS behavioral disturbance. Modeling also indicates there would 44 exposures to impulsive sound or pressures from explosive sources of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and one exposure to impulsive sound or pressures from explosive sources that would cause slight physical injury (Table 6-8).

Nothern fur seals make short duration dives and often rest at the surface (Antonelis et al. 1990) making them easier to detect.

Based on the model results, behavioral patterns, acoustic abilities of northern fur seals, results of past training, and the implementation of procedure mitigation measures presented in Section 11, the Navy finds that the NWTRC training events would not result in any population level effects, death or injury to northern fur seals. At this time, this application requests authorization for the annual harassment of 1,346 northern fur seals by MMPA Level B harassment (1,278 from mid-frequency active sonar and 68 from explosive sources) and one northern fur seals by MMPA Level A harassment from explosive sources.

7 IMPACTS TO MARINE MAMMAL SPECIES OR STOCKS

Overall, the conclusions in this analysis find that impacts to marine mammal species and stocks would be negligible for the following reasons:

- Most acoustic harassments are within the non-injurious temporary threshold shift (TTS) or behavioral effects zones (Level B harassment). Thirteen exposures to sound levels or pressure that could cause permanent threshold shift (PTS)/injury (Level A harassment) resulted from the summation of the modeling.

- Although the numbers presented in Tables 6-7 and 6-8 represent estimated harassment under the Marine Mammal Protection Act (MMPA), as described above, they are conservative estimates of harassment, primarily by behavioral disturbance. In addition, the model calculates harassment without taking into consideration standard mitigation measures, and is not indicative of a likelihood of either injury or harm.

- Additionally, the mitigation measures described in Chapter 11 are designed to reduce sound exposure of marine mammals to levels below those that may cause "behavioral disruptions" and to achieve the least practicable adverse effect on marine mammal species or stocks.

Consideration of negligible impact is required for National Marine Fisheries Service (NMFS) to authorize incidental take of marine mammals. By definition, an activity has a "negligible impact" on a species or stock when it is determined that the total taking is not likely to reduce annual rates of adult survival or recruitment (i.e., offspring survival, birth rates). Using each species' life history information, the expected behavioral patterns in the Northwest Training Range Complex (NWTRC) training and exercise locations, and an analysis of the behavioral disturbance levels in comparison to the overall population presented for each species, these species-specific analyses support the conclusion that proposed NWTRC training events would have a negligible impact on marine mammal populations.

This authorization request assumes that short-term non-injurious sound exposure levels predicted to cause TTS or temporary behavioral disruptions qualify as MMPA Level B harassment. As discussed, this will overestimate reactions qualifying as harassment under MMPA because there is no established scientific correlation between mid-frequency active sonar use and long term abandonment or significant alteration of behavioral patterns in marine mammals. As detailed in Table 6-7 and Table 6-8, there are 129,570 MMPA Level B takes (Risk Function and TTS), 13 MMPA Level A takes, and no takes for mortality in this authorization request.

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8   IMPACT ON SUBSISTENCE USE

Potential impacts resulting from the Proposed Action will be limited to individuals of marine mammal species located in the Northwest Training Range Complex that have no subsistence requirements. Therefore, no impacts on the availability of species or stocks for subsistence use are considered.

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9   IMPACTS TO THE MARINE MAMMAL HABITAT AND THE LIKELIHOOD OF RESTORATION

The primary source of potential marine mammal habitat impact is acoustic exposures resulting from anti-submarine warfare (ASW) activities. However, the exposures do not constitute a long-term physical alteration of the water column or bottom topography, as the occurrences are of limited duration and are intermittent in time. Surface vessels associated with the activities are present in limited duration and are intermittent as they are continuously and relatively rapidly moving through any given area. Activities involving explosive sources, such as bombing exercises (BOMBEX), gunnery exercises (GUNEX), missile exercises (MISSILEX), and sinking exercises (SINKEX) do not constitute a long-term physical alteration of the water column or bottom topography, as the occurrences are of limited duration and are intermittent in time. Underwater detonations for mine or obstruction clearance and amphibious landings occur in sandy shallow areas and will not affect foraging or haul-out habitats.

9.1 Water Quality

The NWTRC EIS/OEIS analyzed the potential effects to water quality Expendable Mobile ASW Training Target (EMATT) batteries. In addition, sonobuoys were not analyzed since, once scuttled, their electrodes are largely exhausted during use and residual constituent dissolution occurs more slowly than the releases from activated seawater batteries. As such, only the potential effects of batteries and explosions on marine water quality in and surrounding the sonobuoy training area were completed. It was determined that there would be no significant effect to water quality from seawater batteries, lithium batteries, and thermal batteries associated with scuttled sonobuoys.

EMATTs use lithium sulfur dioxide batteries. The constituents in the battery react to form soluble hydrogen gas and lithium dithionite. The hydrogen gas eventually enters the atmosphere and the lithium hydroxide dissociates, forming lithium ions and hydroxide ions. The hydroxide is neutralized by the hydronium formed from hydrolysis of the acidic sulfur dioxide, ultimately forming water. Sulfur dioxide, a gas that is highly soluble in water, is the major reactive component in the battery. The sulfur ioxide ionizes in the water, forming bisulfite (HSO_3) that is easily oxidized to sulfate in the slightly alkaline environment of the ocean. Sulfur is present as sulfate in large quantities (i.e., 885 milligrams per liter [mg/L]) in the ocean. Thus, it was determined that there would be no significant effect to water quality from lithium sulfur batteries associated with scuttled EMATTs.

9.2 Sound

9.2.1 Sound in the Environment

The potential cumulative impact issue associated with active sonar activities is the addition of underwater sound to oceanic ambient noise levels, which in turn could have potential effects on marine animals. Anthropogenic sources of ambient noise that are most likely to have contributed to increases in ambient noise levels are commercial shipping, offshore oil and gas exploration and drilling, and naval and other use of sonar (Advisory Committee On Acoustic Impacts to Marine Mammals 2006). The potential impact that mid- and high-frequency sonars may have on the overall oceanic ambient noise level are reviewed in the following contexts:

- Recent changes to ambient sound levels in the Pacific Ocean;

- Operational parameters of the sonar operating during NWTRC activities, including proposed mitigation;

- The contribution of active sonar activities to oceanic noise levels relative to other human-generated sources of oceanic noise; and

- Cumulative impacts and synergistic effects.

Sources of oceanic ambient noise, including physical, biological, and anthropogenic, are presented in the NWTRC EIS/OEIS. Very few studies have been conducted to determine ambient sound levels in the ocean. However, ambient sound levels for the Eglin Gulf Test and Training Range, located in the Gulf of Mexico, generally range from approximately 40 dB to about 110 dB (U.S. Air Force 2002). In a study conducted by Andrew et al. (2002), ocean ambient sound from the 1960s was compared to ocean ambient sound from the 1990s for a receiver off the coast of California (Andrew et al. 2002). The data showed an increase in ambient noise of approximately 10 dB in the frequency range of 20 to 80 Hz, and 200 to 300 Hz, and about 3 dB at 100 Hz over a 33-year period (Andrew et al. 2002).

Anthropogenic sound can be introduced into the ocean by a number of sources, including vessel traffic, industrial operations onshore, seismic profiling for oil exploration, oil drilling, and sonar use. In open oceans, the primary persistent anthropogenic sound source tends to be commercial shipping, since over 90 percent of global trade depends on transport across the seas (Scowcroft et al. 2006). Moreover, there are approximately 20,000 large commercial vessels at sea worldwide at any given time. The large commercial vessels produce relatively loud and predominately low-frequency sounds. Most of these sounds are produced as a result of propeller cavitation (when air spaces created by the motion of propellers collapse) (Southall 2005). In 2004, NOAA hosted a symposium entitled, "Shipping Noise and Marine Mammals." During Session I, Trends in the Shipping Industry and Shipping Noise, statistics were presented that indicate foreign waterborne trade into the United States has increased 2.45 percent each year over a 20-year period (1981 to 2001) (Southall 2005). International shipping volumes and densities are expected to continually increase in the foreseeable future (Southall 2005). The increase in shipping volumes and densities will most likely increase overall ambient sound levels in the ocean. However, it is not known whether these increases would have an effect on marine mammals (Southall 2005).

According to the NRC (2003), the oil and gas industry has five categories of activities which create sound: seismic surveys, drilling, offshore structure emplacement, offshore structure removal, and production and related activities. Seismic surveys are conducted using air guns, sparker sources, sleeve guns, innovative new impulsive sources and sometimes explosives, and are routinely conducted in offshore exploration and production operations in order to define subsurface geological structure. The resultant seismic data are necessary for determining drilling location and currently seismic surveys are the only method to accurately find hydrocarbon reserves. Since the reserves are deep in the earth, the low frequency band (5 to 20 Hz) is of greatest value for seismic surveys, because lower frequency signals are able to travel farther into the seafloor with less attenuation (DoN 2007a).

The air gun firing rate is dependent on the distance from the array to the substrate. The typical intershot time is 9 to 14 seconds, but for very deep water surveys, inter-shot times are as high as 42 seconds. Air gun acoustic signals are broadband and typically measured in peak-to-peak pressures. Peak levels from the air guns are generally higher than continuous sound levels from any other ship or industrial noise. Broadband SLs of 248 to 255 dB from zero-to-peak are

typical for a full-scale array. The most powerful arrays have source levels as high as 260 dB, zero to-peak with air gun volumes of 130 L (7,900 in3). Smaller arrays have SLs of 235 to 246 dB, zero-to peak.

For deeper-water surveys, most emitted energy is around 10 to 120 Hz. However, some pulses contain energy up to 1,000 Hz (Richardson et al. 1995), and higher. Drill ship activities are one of the noisiest at-sea activities because the hull of the ship is a good transmitter of all the ship's internal noises. In addition, the ships use thrusters to stay in the same location rather than anchoring. Auxiliary noise is produced during drilling activities, such as helicopter and supply boat noises. Offshore drilling structure emplacement creates some localized noise for brief periods of time, and emplacement activities can last for a few weeks and occur worldwide. Additional noise is created during other oil production activities, such as borehole logging, cementing, pumping, and pile driving. Although sound pressure levels for some of these activities have not yet been calculated, others have (e.g., pile-driving). These oil and gas industry activities occur year-round (not individual surveys, but collectively) and are usually operational 24 hours per day and 7 days per week.

There are both military and commercial sonars: military sonars are used for target detection, localization, and classification; commercial sonars are typically higher in frequency and lower in power and are used for depth sounding, bottom profiling, fish finding, and detecting obstacles in the water. Commercial sonar use is expected to continue to increase, although it is not believed that the acoustic characteristics will change. Even though an animal's exposure to active sonar may be more than one time, the intermittent nature of the sonar signal, its low duty cycle, and the fact that both the vessel and animal are moving provide a very small chance that exposure to active sonar for individual animals and stocks would be repeated over extended periods of time, such as those caused by shipping noise.

9.2.2 Sound Effects of Food Resources

9.2.2.1 Fish resources

The data obtained to date on effects of sound on fish are very limited both in terms of number of well controlled studies and in number of species tested. Moreover, there are significant limits in the range of data available for any particular type of sound source. Finally, most of the data currently available has little to do with actual behavior of fish in response to sound in their normal environment. As discussed, the extent of data, and particularly scientifically peer-reviewed data, on the effects of high intensity sounds on fish is exceedingly limited (Popper et al. 2007; Popper 2008). Some of these limitations include:

Types of sources tested; Effects of individual sources as they vary by such things as intensity, repetition rate, spectrum, distance to the animal, etc.; Number of species tested with any particular source; The ability to extrapolate between species that are anatomically, physiologically, and/or taxonomically, different; Potential differences, even within a species as related to fish size (and mass) and/or developmental history; Differences in the sound field at the fish, even when studies have used the same type of sound source (e.g., seismic airgun); Poor quality experimental design and controls in many of the studies to date; Lack of behavioral studies that examine the effects on, and responses of, fish in their natural habitat to high intensity signals; Lack of studies on how sound may impact stress, and the short- and long-term effects of acoustic stress on fish; and Lack of studies on eggs and larvae that specifically use sounds of interest to the Navy.

At the same time, in considering potential sources that are in the mid- and high-frequency range, a number of potential effects are clearly eliminated. Most significantly, since the vast majority of fish species studied to date are hearing generalists and cannot hear sounds above 500 to 1,500 Hz (0.5 to 1.5 kHz) (depending upon the species), there are not likely to be behavioral effects on these species from higher frequency sounds such as MFA/HFA sonar.

Moreover, even those marine species that may hear above 1.5 kHz, such as a few sciaenids and the clupeids (and relatives), have relatively poor hearing above 1.5 kHz as compared to their hearing sensitivity at lower frequencies. Thus, it is reasonable to suggest that even among the species that have hearing ranges that overlap with some mid- and high-frequency sounds, it is likely that the fish will only actually hear the sounds if the fish and source are very close to one another. And, finally, since the vast majority of sounds that are of biological relevance to fish are below 1 kHz (e.g., Zelick et al. 1999; Ladich and Popper 2004), even if a fish detects a mid- or high-frequency sound, these sounds will not mask detection of lower frequency biologically relevant sounds. Thus, a reasonable conclusion, even without more data, is that there will be few, and more likely no, impacts on the behavior of fish. At the same time, it is possible that very intense mid- and high-frequency signals, and particularly explosives, could have a physical impact on fish, resulting in damage to the swim bladder and other organ systems. However, even these kinds of effects have only been shown in a few cases in response to explosives, and only when the fish has been very close to the source. Such effects have never been shown to any Navy sonar. Moreover, at greater distances (the distance clearly would depend on the intensity of the signal from the source) there appears to be little or no impact on fish, and particularly no impact on fish that do not have a swim bladder or other air bubble that would be affected by rapid pressure changes.

9.2.2.2   Invertebrates Food Resources

Very little is known about sound detection and use of sound by invertebrates (see Budelmann 1992a, b, Popper et al. 2001 for reviews). The limited data shows that some crabs are able to detect sound, and there has been the suggestion that some other groups of invertebrates are also able to detect sounds. In addition, cephalopods (octopus and squid) and decapods (lobster, shrimp, and crab) are thought to sense low-frequency sound (Budelmann 1992b). Packard et al. (1990) reported sensitivity to sound vibrations between 1-100 Hz for three species of cephalopods. McCauley et al. (2000) found evidence that squid exposed to seismic airguns show a behavioral response including inking. However, these were caged animals, and it is not clear how unconfined animals may have responded to the same signal and at the same distances used. In another study, Wilson et al. (2007) played back echolocation clicks of killer whales to two groups of squid (Loligo pealeii) in a tank. The investigators observed no apparent behavioral effects or any acoustic debilitation from playback of signals up to 199 to 226 dB re 1 μPa. It should be noted, however, that the lack of behavioral response by the squid may have been because the animals were in a tank rather than being in the wild. In another report on squid, Guerra et al. (2004) claimed that dead giant squid turned up around the time of seismic airgun operations off of Spain. The authors suggested, based on analysis of carcasses, that the damage to the squid was unusual when compared to other dead squid found at other times. However, the report presents conclusions based on a correlation to the time of finding of the carcasses and seismic testing, but the evidence in support of an effect of airgun activity was totally circumstantial. Moreover, the data presented showing damage to tissue is highly questionable since there was no way to differentiate between damage due to some external cause (e.g., the

seismic airgun) and normal tissue degradation that takes place after death, or due to poor fixation and preparation of tissue. To date, this work has not been published in peer reviewed literature, and detailed images of the reportedly damaged tissue are also not available.

In summary, baleen whales feed on the aggregations of krill and small schooling fish, while toothed whales feed on epipelagic, mesopelagic, and bathypelagic fish and squid. As summarized above and in the NWTRC EIS/OEIS in more detail, potential impacts to marine mammal food resources within the NWTRC is negligible given both lack of hearing sensitivity to mid-frequency sonar, the very geographic and spatially limited scope of most Navy at sea activities including underwater detonations, and the high biological productivity of these resources. No short or long term effects to marine mammal food resources from Navy activities are anticipated within the NWTRC.

9.3 Vessel Movement

Collisions with commercial and Navy ships can cause major wounds and may occasionally cause fatalities to cetaceans. The most vulnerable marine mammals are those that spend extended periods of time at the surface in order to restore oxygen levels within their tissues after deep dives (e.g., sperm whale). In addition, some baleen whales, such as the northern right whale and fin whale swim slowly and seem generally unresponsive to ship sound, making them more susceptible to ship strikes (Nowacek et al. 2004). Smaller marine mammals, for example, the delphinids move quickly throughout the water column and are often seen riding the bow wave of large ships. Marine mammal responses to vessels may include avoidance and changes in dive pattern (NRC 2003).

Unlike many commercial and recreational ships and boats, Navy ships usually maintain as low a speed as practical in terms of the tactical and transit considerations for a particular event in order to economize on fuel and associated fuel costs. In addition, each Navy vessel has at least three lookouts maintaining a visual search of the surrounding water during non-ASW events, and five lookouts during ASW-events. Not included in this count are additional observers involved with safe navigation (Officer of the Deck, Conning Officer, and other personnel on the bridge watch).

The Navy has adopted mitigation measures that reduce the potential for collisions with surfaced marine mammals and sea turtles (See Section 11). These standard operating procedures include: (1) use of lookouts trained to detect all objects on the surface of the water, including marine mammals; (2) reasonable and prudent actions to avoid the close interaction of Navy assets and marine mammals; and (3) maneuvering to keep away from any observed marine mammal. Based on these standard operating procedures, collisions with marine mammals are not expected.

9.4 Torpedoes

There is a negligible risk that a marine mammal could be struck by a torpedo during ASW training activities. This conclusion is based on (1) review of torpedo design features, and (2) review of a large number of previous naval exercise ASW torpedo activities. The acoustic homing programs of torpedoes are designed to detect either the mechanical sound signature of the submarine or active sonar returns from its metal hull with large internal air volume interface. The torpedoes are specifically designed to ignore false targets. As a result, their homing logic does not detect or recognize the relatively small air volume associated with the lungs of marine mammals. They do not detect or home to marine mammals. The Navy has conducted exercise torpedo activities since 1968. At least 14,322 exercise torpedo runs have been conducted since

1968. There have been no recorded or reported instances of a marine species strike by an exercise torpedo. Every exercise torpedo activity is monitored acoustically by on-scene range personnel listening to range hydrophones positioned on the ocean floor in the immediate vicinity of the torpedo activity. After each torpedo run, the recovered exercise torpedo is thoroughly inspected for any damage. The torpedoes then go through an extensive production line refurbishment process for re-use. This production line has stringent quality control procedures to ensure that the torpedo will safely and effectively operate during its next run. Since these exercise torpedoes are frequently used against manned Navy submarines, this post activity inspection process is thorough and accurate. Inspection records and quality control documents are prepared for each torpedo run. This post exercise inspection is the basis that supports the conclusion of negligible risk of marine mammal strike. Therefore, there will be no significant impact and no significant harm to marine mammals resulting from interactions with torpedoes during NWTRC activities. The probability of direct strike of torpedoes associated with NWTRC training is negligible and therefore will have no effect on marine mammal species.

9.5 Military Expendable Material

Marine mammals are subject to entanglement in expended materials, particularly anything incorporating loops or rings, hooks and lines, or sharp objects. Most documented cases of entanglements occur when whales encounter the vertical lines of fixed fishing gear. This section summarizes the potential effects of expended materials on marine mammals. Detailed discussion of military expendable material is contained within the NWTRC EIS/OEIS.

The Navy endeavors to recover expended training materials. Notwithstanding, it is not possible to recover all training debris, and some may be encountered by marine mammals in the waters of the NWTRC. Debris related to military activities that is not recovered generally sinks; the amount that might remain on or near the sea surface is low, and the density of such debris in the NWTRC would be very low. Types of training debris that might be encountered include: parachutes of various types (e.g., those employed by personnel or on targets, flares, or sonobuoys); torpedo guidance wires, torpedo "flex hoses;" cable assemblies used to facilitate target recovery; sonobuoys; and EMATT.

Entanglement in military expendable material was not cited as a source of injury or mortality for any marine mammals recorded in a large marine mammal and sea turtle stranding database for California waters, an area with much higher density of marine mammals. Therefore as discussed in the NWTRC EIS/OEIS, expendable material is highly unlikely to directly affect marine mammal species or potential habitat within the NWTRC.

9.6 Summary

Based on detailed review within the NWTRC EIS/OEIS and summarized within this section, there will be no effects to marine mammals resulting from loss or modification of marine mammal habitat including water quality, food resources, vessel movement, and expendable material. Marine mammal habitat would not be affected.

10 IMPACTS TO MARINE MAMMALS FROM LOSS OR MODIFICATION OF MARINE HABITAT

Based on the discussions in Chapter 9, there will be no impacts to marine mammals resulting from loss or modification of marine mammal habitat.

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11 MEANS OF EFFECTING THE LEAST PRACTICABLE ADVERSE IMPACTS – MITIGATION MEASURES

Effective training in the Northwest Training Range Complex (NWTRC) dictates that ship, submarine, and aircraft participants utilize their sensors and exercise weapons to their optimum capabilities as required by the mission. The Navy recognizes that such use has the potential to cause behavioral disruption of some marine mammal species in the vicinity of an training activity (as outlined in Chapter 6). Although any disruption of natural behavioral patterns is not likely to be to a point where such behavioral patterns are abandoned or significantly altered at the population level, this Chapter presents the Navy's mitigation measures, outlining steps that would be implemented to protect individual marine mammals and Federally-ESA listed species during activities. It should be noted that these mitigation measures have been standard operating procedures for unit level anti-submarine warfare (ASW) training since 2004. In addition, the Navy coordinated with the National Marine Fisheries Service (NMFS) to further develop measures for protection of marine mammals during the period of the National Defense Exemption (NDE), and those mitigations for mid-frequency active sonar are detailed in this Section. This Chapter also presents a discussion of other measures that have been considered and rejected because they are either: (1) not feasible; (2) present a safety concern; (3) provide no known or ambiguous mitigation benefit; or (4) impact the effectiveness of the required ASW training military readiness activity.

A Letter of Instruction, Mitigation Measures Message or Environmental Annex to the Operational Order will be issued prior to each exercise to further disseminate the personnel training requirement and general marine mammal mitigation measures including monitoring and reporting. The Navy will continue to fund marine mammal research as outlined in Chapter 14.

This section includes mitigation measures that are followed for all types of exercises; those that are associated with a particular type of training event; and those that apply generally to all Navy training at sea. Appropriate measures are also provided to non-Navy participants (other DoD and allied forces) as information in order to ensure their use by these participants.

11.1 General Maritime Measures

11.1.1 Personnel Training – Lookouts

The use of shipboard lookouts is a critical component of all Navy protective measures. Navy shipboard lookouts are highly qualified and experienced observers of the marine environment. Their duties require that they report all objects sighted in the water to the officer of the deck (OOD) (e.g., trash, a periscope, marine mammals, sea turtles) and all disturbances (e.g., surface disturbance, discoloration) that may be indicative of a threat to the vessel and its crew. There are personnel serving as lookouts on station at all times (day and night) when a ship or surfaced submarine is moving through the water.

- All commanding officers (COs), executive officers (XOs), lookouts, OODs, junior OODs (JOODs), maritime patrol aircraft aircrews, and Anti-submarine Warfare (ASW)/Mine Warfare (MIW) helicopter crews will complete the NMFS-approved Marine Species Awareness Training (MSAT) by viewing the U.S. Navy MSAT digital versatile disk (DVD). MSAT may also be viewed on-line at https://mmrc.tecquest.net. All bridge lookouts will complete both parts one and two of the MSAT; part two is optional for other personnel. This training addresses the lookout's role in environmental protection,

laws governing the protection of marine species, Navy stewardship commitments and general observation information to aid in avoiding interactions with marine species.

- Navy lookouts will undertake extensive training in order to qualify as a watchstander in accordance with the Lookout Training Handbook (Naval Education and Training Command [NAVEDTRA] 12968-B).

- Lookout training will include on-the-job instruction under the supervision of a qualified, experienced lookout. Following successful completion of this supervised training period, lookouts will complete the Personal Qualification Standard Program, certifying that they have demonstrated the necessary skills (such as detection and reporting of partially submerged objects). Personnel being trained as lookouts can be counted among those listed below as long as supervisors monitor their progress and performance.

- Lookouts will be trained in the most effective means to ensure quick and effective communication within the command structure in order to facilitate implementation of protective measures if marine species are spotted.

11.1.2 Operating Procedures & Collision Avoidance

- Prior to major exercises, a Letter of Instruction, Mitigation Measures Message or Environmental Annex to the Operational Order will be issued to further disseminate the personnel training requirement and general marine species protective measures.

- COs will make use of marine species detection cues and information to limit interaction with marine species to the maximum extent possible consistent with safety of the ship.

- While underway, surface vessels will have at least two lookouts with binoculars; surfaced submarines will have at least one lookout with binoculars. Lookouts already posted for safety of navigation and man-overboard precautions may be used to fill this requirement. As part of their regular duties, lookouts will watch for and report to the OOD the presence of marine mammals and sea turtles.

- On surface vessels equipped with a multi-function active sensor, pedestal mounted "Big Eye" (20x10) binoculars will be properly installed and in good working order to assist in the detection of marine mammals and sea turtles in the vicinity of the vessel.

- Personnel on lookout will employ visual search procedures employing a scanning methodology in accordance with the Lookout Training Handbook (NAVEDTRA 12968-B).

- After sunset and prior to sunrise, lookouts will employ Night Lookouts Techniques in accordance with the Lookout Training Handbook. (NAVEDTRA 12968-B)

- While in transit, naval vessels will be alert at all times, use extreme caution, and proceed at a "safe speed" so that the vessel can take proper and effective action to avoid a collision with any marine animal and can be stopped within a distance appropriate to the prevailing circumstances and conditions.

- When whales have been sighted in the area, Navy vessels will increase vigilance and take reasonable and practicable actions to avoid collisions and activities that might result in close interaction of naval assets and marine mammals. Actions may include changing speed and/or direction and are dictated by environmental and other conditions (e.g., safety, weather).

- Naval vessels will maneuver to keep at least 1,500 ft (460 m) away from any observed whale and avoid approaching whales head-on. This requirement does not apply if a vessel's safety is threatened, such as when change of course will create an imminent and serious threat to a person, vessel, or aircraft, and to the extent vessels are restricted in their ability to maneuver. Restricted maneuverability includes, but is not limited to, situations when vessels are engaged in dredging, submerged activities, launching and recovering aircraft or landing craft, minesweeping activities, replenishment while underway and towing activities that severely restrict a vessel's ability to deviate course. Vessels will take reasonable steps to alert other vessels in the vicinity of the whale.

- Where feasible and consistent with mission and safety, vessels will avoid closing to within 200-yd of sea turtles and marine mammals other than whales (whales addressed above).

- Floating weeds and kelp, algal mats, clusters of seabirds, and jellyfish are good indicators of sea turtles and marine mammals. Therefore, increased vigilance in watching for sea turtles and marine mammals will be taken where these are present.

- Navy aircraft participating in exercises at sea will conduct and maintain, when operationally feasible and safe, surveillance for marine species of concern as long as it does not violate safety constraints or interfere with the accomplishment of primary operational duties. Marine mammal detections will be immediately reported to assigned Aircraft Control Unit for further dissemination to ships in the vicinity of the marine species as appropriate where it is reasonable to conclude that the course of the ship will likely result in a closing of the distance to the detected marine mammal.

- All vessels will maintain logs and records documenting training activities should they be required for event reconstruction purposes. Logs and records will be kept for a period of 30 days following completion of a major training exercise.

11.2 Measures for Specific Training Events

11.2.1 Mid-Frequency Active Sonar Activities

General Maritime Mitigation Measures: Personnel Training

- All lookouts onboard platforms involved in ASW training events will review the NMFS-approved Marine Species Awareness Training material prior to use of mid-frequency active sonar.
- All COs, XOs, and officers standing watch on the bridge will have reviewed the Marine Species Awareness Training material prior to a training event employing the use of mid-frequency active sonar.
- Navy lookouts will undertake extensive training in order to qualify as a watchstander in accordance with the Lookout Training Handbook (Naval Educational Training [NAVEDTRA], 12968-B).
- Lookout training will include on-the-job instruction under the supervision of a qualified, experienced watchstander. Following successful completion of this supervised training period, lookouts will complete the Personal Qualification Standard program, certifying that they have demonstrated the necessary skills (such as detection and reporting of partially submerged objects). This does not forbid personnel being trained as lookouts

from being counted as those listed in previous measures so long as supervisors monitor their progress and performance.

- Lookouts will be trained in the most effective means to ensure quick and effective communication within the command structure in order to facilitate implementation of mitigation measures if marine species are spotted.

General Maritime Mitigation Measures: Lookout and Watchstander Responsibilities

- On the bridge of surface ships, there will always be at least three people on watch whose duties include observing the water surface around the vessel.

- All surface ships participating in ASW training events will, in addition to the three personnel on watch noted previously, have at all times during the exercise at least two additional personnel on watch as marine mammal lookouts.

- Personnel on lookout and officers on watch on the bridge will have at least one set of binoculars available for each person to aid in the detection of marine mammals.

- On surface vessels equipped with mid-frequency active sonar, pedestal mounted "Big Eye" (20x110) binoculars will be present and in good working order to assist in the detection of marine mammals in the vicinity of the vessel.

- Personnel on lookout will employ visual search procedures employing a scanning methodology in accordance with the Lookout Training Handbook (NAVEDTRA 12968-B).

- After sunset and prior to sunrise, lookouts will employ Night Lookouts Techniques in accordance with the Lookout Training Handbook.

- Personnel on lookout will be responsible for reporting all objects or anomalies sighted in the water (regardless of the distance from the vessel) to the Officer of the Deck, since any object or disturbance (e.g., trash, periscope, surface disturbance, discoloration) in the water may be indicative of a threat to the vessel and its crew or indicative of a marine species that may need to be avoided as warranted.

Operating Procedures

- A Letter of Instruction, Mitigation Measures Message, or Environmental Annex to the Operational Order will be issued prior to the exercise to further disseminate the personnel training requirement and general marine mammal mitigation measures.

- COs will make use of marine species detection cues and information to limit interaction with marine species to the maximum extent possible consistent with safety of the ship.

- All personnel engaged in passive acoustic sonar operation (including aircraft, surface ships, or submarines) will monitor for marine mammal vocalizations and report the detection of any marine mammal to the appropriate watch station for dissemination and appropriate action.

- During mid-frequency active sonar activities, personnel will utilize all available sensor and optical systems (such as night vision goggles) to aid in the detection of marine mammals.

- Navy aircraft participating in exercises at sea will conduct and maintain, when operationally feasible and safe, surveillance for marine species of concern as long as it does not violate safety constraints or interfere with the accomplishment of primary operational duties.

- Aircraft with deployed sonobuoys will use only the passive capability of sonobuoys when marine mammals are detected within 200 yds (183 m) of the sonobuoy.

- Marine mammal detections will be immediately reported to assigned Aircraft Control Unit for further dissemination to ships in the vicinity of the marine species as appropriate where it is reasonable to conclude that the course of the ship will likely result in a closing of the distance to the detected marine mammal.

- Safety Zones—When marine mammals are detected by any means (aircraft, shipboard lookout, or acoustically) within 1,000 yds (914 m) of the sonar dome (the bow), the ship or submarine will limit active transmission levels to at least 6 decibels (dB) below normal operating levels. (A 6 dB reduction equates to a 75 percent power reduction. The reason is that decibel levels are on a logarithmic scale, not a linear scale. Thus, a 6 dB reduction results in a power level only 25 percent of the original power.)

  o Ships and submarines will continue to limit maximum transmission levels by this 6-dB factor until the animal has been seen to leave the area, has not been detected for 30 minutes, or the vessel has transited more than 2,000 yds (1,829 m) beyond the location of the last detection.

  o Should a marine mammal be detected within or closing to inside 500 yds (457 m) of the sonar dome, active sonar transmissions will be limited to at least 10 dB below the equipment's normal operating level. (A 10 dB reduction equates to a 90 percent power reduction from normal operating levels.) Ships and submarines will continue to limit maximum ping levels by this 10-dB factor until the animal has been seen to leave the area, has not been detected for 30 minutes, or the vessel has transited more than 2,000 yds (1,829 m) beyond the location of the last detection.

  o Should the marine mammal be detected within or closing to inside 200 yds (183 m) of the sonar dome, active sonar transmissions will cease. Sonar will not resume until the animal has been seen to leave the area, has not been detected for 30 minutes, or the vessel has transited more than 2,000 yds (1,829 m) beyond the location of the last detection.

  o Special conditions applicable for dolphins and porpoises only: If, after conducting an initial maneuver to avoid close quarters with dolphins or porpoises, the OOD concludes that dolphins or porpoises are deliberately closing to ride the vessel's bow wave, no further mitigation actions are necessary while the dolphins or porpoises continue to exhibit bow wave riding behavior.

  o If the need for power-down should arise as detailed in "Safety Zones" above, the Navy shall follow the requirements as though they were operating at 235 dB—the normal operating level (i.e., the first power-down will be to 229 dB, regardless of at what level above 235 sonar was being operated).

- Prior to start up or restart of active sonar, operators will check that the Safety Zone radius around the sound source is clear of marine mammals.

- Sonar levels (generally)—Navy will operate sonar at the lowest practicable level, not to exceed 235 dB, except as required to meet tactical training objectives.

- Helicopters shall observe/survey the vicinity of an ASW training event for 10 minutes before the first deployment of active (dipping) sonar in the water.

- Helicopters shall not dip their sonar within 200 yds (183 m) of a marine mammal and shall cease pinging if a marine mammal closes within 200 yds (183 m) after pinging has begun.

- Submarine sonar operators will review detection indicators of close-aboard marine mammals prior to the commencement of ASW training events involving active mid-frequency sonar.

- Increased vigilance during ASW training events with tactical active sonar when critical conditions are present.

  Based on lessons learned from strandings in Bahamas 2000, Madeiras 2000, Canaries 2002 and Spain 2006, beaked whales are of particular concern since they have been associated with mid-frequency active sonar activities. The Navy should avoid planning Major ASW Training Exercises with mid-frequency active sonar in areas where they will encounter conditions which, in their aggregate, may contribute to a marine mammal stranding event.

  The conditions to be considered during exercise planning include:

  o Areas of at least 1,000-meter depth near a shoreline where there is a rapid change in bathymetry on the order of 1,000-6,000 yds (914-5486 m) occurring across a relatively short horizontal distance (e.g., 5 nm [9 km]).

  o Cases for which multiple ships or submarines ($\geq$ 3) operating mid-frequency active sonar in the same area over extended periods of time ($\geq$ 6 hours) in close proximity ($\leq$ 10 nm [19 km] apart).

  o An area surrounded by land masses, separated by less than 35 nm (65 km) and at least 10 nm (19 km) in length, or an embayment, wherein activities involving multiple ships/subs ($\geq$ 3) employing mid-frequency active sonar near land may produce sound directed toward the channel or embayment that may cut off the lines of egress for marine mammals.

  o Though not as dominant a condition as bathymetric features, the historical presence of a significant surface duct (i.e., a mixed layer of constant water temperature extending from the sea surface to 100 ft [30 m] or more).

If the Major Range Event is to occur in an area where the above conditions exist in their aggregate, these conditions must be fully analyzed in environmental planning documentation. The Navy will increase vigilance by undertaking the following additional mitigation measure:

- A dedicated aircraft (Navy asset or contracted aircraft) will undertake reconnaissance of the embayment or channel ahead of the exercise participants to detect marine mammals

that may be in the area exposed to active sonar. Where practical, advance survey should occur within about 2 hours prior to mid-frequency active sonar use and periodic surveillance should continue for the duration of the exercise. Any unusual conditions (e.g., presence of sensitive species, groups of species milling out of habitat, and any stranded animals) shall be reported to the Office in Tactical Command, who should give consideration to delaying, suspending, or altering the exercise.

- All safety zone power down requirements described above will apply.

- The post-exercise report must include specific reference to any event conducted in areas where the above conditions exist, with exact location and time/duration of the event, and noting results of surveys conducted.

11.2.2 Surface-to-Surface Gunnery (5-inch, 76 mm, 20 mm, 25 mm and 30 mm explosive rounds)

- Lookouts will visually survey for floating weeds and kelp, and algal mats which may be inhabited by immature sea turtles in the target area. Intended impact shall not be within 600 yds (585 m) of known or observed floating weeds and kelp, and algal mats.

- For exercises using targets towed by a vessel or aircraft, target-towing vessels/aircraft shall maintain a trained lookout for marine mammals and sea turtles. If a marine mammal or sea turtle is sighted in the vicinity, the tow aircraft/vessel will immediately notify the firing vessel, which will suspend the exercise until the area is clear.

- A 600 yard radius buffer zone will be established around the intended target.

- From the intended firing position, trained lookouts will survey the buffer zone for marine mammals and sea turtles prior to commencement and during the exercise as long as practicable. Due to the distance between the firing position and the buffer zone, lookouts are only expected to visually detect breaching whales, whale blows, and large pods of dolphins and porpoises.

- The exercise will be conducted only when the buffer zone is visible and marine mammals and sea turtles are not detected within it.

11.2.3 Surface-to-Surface Gunnery (non-explosive rounds)

- Lookouts will visually survey for floating weeds and kelp, and algal mats which may be inhabited by immature sea turtles in the target area. Intended impact will not be within 200 yds (183 m) of known or observed floating weeds and kelp, and algal mats.

- A 200 yd (183 m) radius buffer zone will be established around the intended target.

- From the intended firing position, trained lookouts will survey the buffer zone for marine mammals and sea turtles prior to commencement and during the exercise as long as practicable. Due to the distance between the firing position and the buffer zone, lookouts are only expected to visually detect breaching whales, whale blows, and large pods of dolphins and porpoises.

- If applicable, target towing vessels will maintain a lookout. If a marine mammal or sea turtle is sighted in the vicinity of the exercise, the tow vessel will immediately notify the firing vessel in order to secure gunnery firing until the area is clear.

- The exercise will be conducted only when the buffer zone is visible and marine mammals and sea turtles are not detected within the target area and the buffer zone.

11.2.4 Surface-to-Air Gunnery (explosive and non-explosive rounds)

- Vessels will orient the geometry of gunnery exercises in order to prevent debris from falling in the area of sighted marine mammals, sea turtles, algal mats, and floating kelp.

- Vessels will expedite the recovery of any parachute deploying aerial targets to reduce the potential for entanglement of marine mammals and sea turtles.

- Target towing aircraft shall maintain a lookout. If a marine mammal or sea turtle is sighted in the vicinity of the exercise, the tow aircraft will immediately notify the firing vessel in order to secure gunnery firing until the area is clear.

11.2.5 Small Arms Training - (grenades, explosive and non-explosive rounds)

- Lookouts will visually survey for floating weeds or kelp, algal mats, marine mammals, and sea turtles. Weapons will not be fired in the direction of known or observed floating weeds or kelp, algal mats, marine mammals, sea turtles.

11.2.6 Air-to-Surface At-Sea Bombing Exercises (explosive bombs and cluster munitions, rockets)

- If surface vessels are involved, trained lookouts will survey for floating kelp, which may be inhabited by immature sea turtles. Ordnance shall not be targeted to impact within 1,000 yds (914 m) of known or observed floating kelp, sea turtles, or marine mammals.

- A buffer zone of 1,000 yd (914 m) radius will be established around the intended target.

- Aircraft will visually survey the target and buffer zone for marine mammals and sea turtles prior to and during the exercise. The survey of the impact area will be made by flying at 1,500 feet or lower, if safe to do so, and at the slowest safe speed. Release of ordnance through cloud cover is prohibited: aircraft must be able to actually see ordnance impact areas. Survey aircraft should employ most effective search tactics and capabilities.

- The exercises will be conducted only if marine mammals and sea turtles are not visible within the buffer zone.

11.2.7 Air-to-Surface At-Sea Bombing Exercises (non-explosive bombs and rockets)

- If surface vessels are involved, trained lookouts will survey for floating kelp, which may be inhabited by immature sea turtles, and for sea turtles and marine mammals. Ordnance shall not be targeted to impact within 1,000 yds (914 m) of known or observed floating kelp, sea turtles, or marine mammals.

- A 1,000 yd (914 m) radius buffer zone will be established around the intended target.

- Aircraft will visually survey the target and buffer zone for marine mammals and sea turtles prior to and during the exercise. The survey of the impact area will be made by flying at 1,500 ft (152 m) or lower, if safe to do so, and at the slowest safe speed. Release of ordnance through cloud cover is prohibited: aircraft must be able to actually see ordnance impact areas. Survey aircraft should employ most effective search tactics and capabilities.

- The exercise will be conducted only if marine mammals and sea turtles are not visible within the buffer zone.

11.2.8 Air-to-Surface Missile Exercises (explosive and non-explosive)

- Ordnance shall not be targeted to impact within 1,800 yds (1646 m) of known or observed floating kelp, which may be inhabited by immature sea turtles, or coral reefs.

- Aircraft will visually survey the target area for marine mammals and sea turtles. Visual inspection of the target area will be made by flying at 1,500 ft (457 m) or lower, if safe to do so, and at slowest safe speed. Firing or range clearance aircraft must be able to actually see ordnance impact areas. Explosive ordnance shall not be targeted to impact within 1,800 yds (1646 m) of sighted marine mammals and sea turtles.

11.2.9 Underwater Detonations (up to 2.5-lb charges)

To ensure protection of marine mammals and sea turtles during underwater detonation training, the operating area must be determined to be clear of marine mammals and sea turtles prior to detonation. Implementation of the following mitigation measures continue to ensure that marine mammals would not be exposed to temporary threshold shift (TTS), permanent threshold shift (PTS), or injury from physical contact with training mine shapes during Major Exercises.

Exclusion Zones

All Mine Warfare and Mine Countermeasures Activities involving the use of explosive charges must include exclusion zones for marine mammals and sea turtles to prevent physical and/or acoustic effects to those species. These exclusion zones shall extend in a 700-yard (640-m) arc radius around the detonation site.

Pre-Exercise Surveys

For Demolition and Ship Mine Countermeasures Activities, pre-exercise survey shall be conducted within 30 minutes prior to the commencement of the scheduled explosive event. The survey may be conducted from the surface, by divers, and/or from the air, and personnel shall be alert to the presence of any marine mammal or sea turtle. Should such an animal be present within the survey area, the exercise shall be paused until the animal voluntarily leaves the area. The Navy will suspend detonation exercises and ensure the area is clear for a full 30 minutes prior to detonation. Personnel will record any protected species marine mammal and sea turtle observations during the exercise as well as measures taken if species are detected within the exclusion zone.

Post-Exercise Surveys

Surveys within the same radius shall also be conducted within 30 minutes after the completion of the explosive event.

Reporting

If there is evidence that a marine mammal or sea turtle may have been stranded, injured or killed by the action, Navy training activities will be immediately suspended and the situation immediately reported by the participating unit to the Officer in Charge of the Exercise (OCE), who will follow Navy procedures for reporting the incident to Commander, Pacific Fleet, Commander, Navy Region Southwest, Environmental Director, and the chain-of-command.

11.2.10 Sinking Exercise

The selection of sites suitable for Sinking Exercises (SINKEXs) involves a balance of operational suitability, requirements established under the Marine Protection, Research and

Sanctuaries Act (MPRSA) permit granted to the Navy (40 Code of Federal Regulations § 229.2), and the identification of areas with a low likelihood of encountering Endangered Species Act (ESA) listed species. To meet operational suitability criteria, locations must be within a reasonable distance of the target vessels' originating location. The locations should also be close to active military bases to allow participating assets access to shore facilities. For safety purposes, these locations should also be in areas that are not generally used by non-military air or watercraft. The MPRSA permit requires vessels to be sunk in waters which are at least 1,000 fathoms (3,000 yds / 2,742 m)) deep and at least 50 nm (93 km) from land.

In general, most listed species prefer areas with strong bathymetric gradients and oceanographic fronts for significant biological activity such as feeding and reproduction. Typical locations include the continental shelf and shelf-edge.

SINKEX Range Clearance Plan

The Navy has developed range clearance procedures to maximize the probability of sighting any ships or protected species in the vicinity of an exercise, which are as follows:

- All weapons firing would be conducted during the period 1 hour after official sunrise to 30 minutes before official sunset.

- Extensive range clearance activities would be conducted in the hours prior to commencement of the exercise, ensuring that no shipping is located within the hazard range of the longest-range weapon being fired for that event.

- Prior to conducting the exercise, remotely sensed sea surface temperature maps would be reviewed. SINKEX would not be conducted within areas where strong temperature discontinuities are present, thereby indicating the existence of oceanographic fronts. These areas would be avoided because concentrations of some listed species, or their prey, are known to be associated with these oceanographic features.

- An exclusion zone with a radius of 1.0 nm (1.9 km) would be established around each target. This exclusion zone is based on calculations using a 990-lb (450-kg) H6 net explosive weight high explosive source detonated 5 ft (1.5 m) below the surface of the water, which yields a distance of 0.85 nm (1.57 km) (cold season) and 0.89 nm (1.65 km) (warm season) beyond which the received level is below the 182 decibels (dB) re: 1 micropascal squared-seconds (μPa2-s) threshold established for the WINSTON S. CHURCHILL (DDG 81) shock trials (U.S. Navy, 2001). An additional buffer of 0.5 nm (0.9 km) would be added to account for errors, target drift, and animal movements. Additionally, a safety zone, which extends from the exclusion zone at 1.0 nm (1.9 km) out an additional 0.5 nm (0.9 km), would be surveyed. Together, the zones extend out 2 nm (3.7 km) from the target.

- A series of surveillance over-flights would be conducted within the exclusion and the safety zones, prior to and during the exercise, when feasible. Survey protocol would be as follows:

    o Overflights within the exclusion zone would be conducted in a manner that optimizes the surface area of the water observed. This may be accomplished through the use of the Navy's Search and Rescue Tactical Aid, which provides the best search altitude, ground speed, and track spacing for the discovery of small, possibly dark objects in the water based on the environmental conditions of the

day. These environmental conditions include the angle of sun inclination, amount of daylight, cloud cover, visibility, and sea state.

o All visual surveillance activities would be conducted by Navy personnel trained in visual surveillance. At least one member of the mitigation team would have completed the Navy's marine mammal training program for lookouts.

o In addition to the overflights, the exclusion zone would be monitored by passive acoustic means, when assets are available. This passive acoustic monitoring would be maintained throughout the exercise. Potential assets include sonobuoys, which can be utilized to detect any vocalizing marine mammals (particularly sperm whales) in the vicinity of the exercise. The sonobuoys would be re-seeded as necessary throughout the exercise. Additionally, passive sonar onboard submarines may be utilized to detect any vocalizing marine mammals in the area. The OCE would be informed of any aural detection of marine mammals and would include this information in the determination of when it is safe to commence the exercise.

o On each day of the exercise, aerial surveillance of the exclusion and safety zones would commence 2 hours prior to the first firing.

o The results of all visual, aerial, and acoustic searches would be reported immediately to the OCE. No weapons launches or firing would commence until the OCE declares the safety and exclusion zones free of marine mammals and threatened and endangered species.

o If a protected species observed within the exclusion zone is diving, firing would be delayed until the animal is re-sighted outside the exclusion zone, or 30 minutes have elapsed. After 30 minutes, if the animal has not been re-sighted it would be assumed to have left the exclusion zone. This is based on a typical dive time of 30 minutes for traveling listed species of concern. The OCE would determine if the listed species is in danger of being adversely affected by commencement of the exercise.

o During breaks in the exercise of 30 minutes or more, the exclusion zone would again be surveyed for any protected species. If protected species are sighted within the exclusion zone, the OCE would be notified, and the procedure described above would be followed.

o Upon sinking of the vessel, a final surveillance of the exclusion zone would be monitored for 2 hours, or until sunset, to verify that no listed species were harmed.

- Aerial surveillance would be conducted using helicopters or other aircraft based on necessity and availability. The Navy has several types of aircraft capable of performing this task; however, not all types are available for every exercise. For each exercise, the available asset best suited for identifying objects on and near the surface of the ocean would be used. These aircraft would be capable of flying at the slow safe speeds necessary to enable viewing of marine vertebrates with unobstructed, or minimally obstructed, downward and outward visibility. The exclusion and safety zone surveys may be cancelled in the event that a mechanical problem, emergency search and rescue, or

other similar and unexpected event preempts the use of one of the aircraft onsite for the exercise.

- Every attempt would be made to conduct the exercise in sea states that are ideal for marine mammal sighting, Beaufort Sea State 3 or less. In the event of a 4 or above, survey efforts would be increased within the zones. This would be accomplished through the use of an additional aircraft, if available, and conducting tight search patterns.

- The exercise would not be conducted unless the exclusion zone could be adequately monitored visually.

- In the unlikely event that any listed species are observed to be harmed in the area, a detailed description of the animal would be taken, the location noted, and if possible, photos taken. This information would be provided to NOAA Fisheries via the Navy's regional environmental coordinator for purposes of identification.

- An after action report detailing the exercise's time line, the time the surveys commenced and terminated, amount, and types of all ordnance expended, and the results of survey efforts for each event would be submitted to NOAA Fisheries.

11.2.11 Multi-static Mitigation Procedures – AN/SSQ-110A

AN/SSQ-110A Pattern Deployment:

- Crews will conduct visual reconnaissance of the drop area prior to laying their intended sonobuoy pattern. This search should be conducted below 1,500 (457 m) at a slow speed when operationally feasible and weather conditions permit. In dual aircraft activities, crews may conduct coordinated area clearances.

- Crews shall conduct a minimum of 30 minutes of visual and aural monitoring of the search area prior to commanding the first post (source/receiver sonobuoy pair) detonation. This 30 minute observation period may include pattern deployment time.

- For any part of the briefed pattern where a post will be deployed within 1,000 yds (914 m) of observed marine mammal activity, crews will deploy the receiver ONLY and monitor while conducting a visual search. When marine mammals are no longer detected within 1,000 yds of the intended post position, crews will co-locate the AN/SSQ-110A sonobuoy (source) with the receiver.

- When operationally feasible, crews will conduct continuous visual and aural monitoring of marine mammal activity, including monitoring of their aircraft sensors from first sensor placement to checking off-station and out of RF range of the sensors.

AN/SSQ-110A Pattern Employment:

- Aural Detection:
  - Aural detection of marine mammals cues the aircrew to increase the diligence of their visual surveillance.
  - If, following aural detection, no marine mammals are visually detected, then the crew may continue multi-static active search.

- Visual Detection:

  o If marine mammals are visually detected within 1000 yds of the AN/SSQ-110A sonobuoy intended for use, then that payload shall not be detonated. Aircrews may utilize this post once the marine mammals have not been re-sighted for 30 minutes or are observed to have moved outside the 1000 yd safety zone.

  o Aircrews may shift their multi-static active search to another post, where marine mammals are outside the 1000 yd safety zone.

AN/SSQ-110A Scuttling Sonobuoys:

- Aircrews shall make every attempt to manually detonate the unexploded charges at each post in the pattern prior to departing the activities area by using the "Payload 1 Release" command followed by the "Payload 2 Release" command. Aircrews shall refrain from using the "Scuttle" command when two payloads remain at a given post. Aircrews will ensure a 1000 yd safety zone, visually clear of marine mammals, is maintained around each post as is done during active search activities.

- Aircrews shall only leave posts with unexploded charges in the event of a sonobuoy malfunction, an aircraft system malfunction, or when an aircraft must immediately depart the area due to issues such as fuel constraints, inclement weather, and in-flight emergencies. In these cases, the sonobuoy will self-scuttle using the secondary method or tertiary method.

- Aircrews ensure all payloads are accounted for. Sonobuoys that cannot be scuttled shall be reported as unexploded ordnance via voice communications while airborne and, upon landing, via Naval message.

- Mammal monitoring shall continue until out of their aircraft sensor range.

11.3 Conservation Measures

11.3.1 NWTRC Marine Species Monitoring Plan

The Navy is developing a Marine Species Monitoring Plan (MSMP) that provides recommendations for site-specific monitoring for MMPA and ESA listed species (primarily marine mammals) within the NWTRC, including during training. The primary goals of monitoring are to evaluate trends in marine species distribution and abundance in order to assess potential population effects from Navy training activities and determine the effectiveness of the Navy's mitigation measures. The information gained from the monitoring will also allow the Navy to evaluate the models used to predict effects to marine mammals and is described fully in Section 13, Monitoring and Reporting Measures.

11.3.2 Research

The Navy provides a significant amount of funding and support to marine research. The agency provides nearly 18 million dollars annually to universities, research institutions, federal laboratories, private companies, and independent researchers around the world to study marine mammals. These research efforts are presented in full in Section 14, Research.

11.4 Coordination and Reporting

The Navy will coordinate with the local NMFS Stranding Coordinator for any unusual marine mammal behavior and any stranding, beached live/dead or floating marine mammals that may occur coincident with Navy training activities.

11.5 Alternative Mitigation Measures Considered but Eliminated

The vast majority of estimated sound exposures of marine mammals during proposed active sonar activities would not cause injury. Potential acoustic effects on marine mammals would be further reduced by the mitigation measures described above. Therefore, the Navy concludes the proposed action and mitigation measures would achieve the least practical adverse impact on species or stocks of marine mammals.

A determination of "least practicable adverse impacts" includes consideration of personnel safety, practicality of implementation, and impact on the effectiveness of the military readiness activity in consultation with the DoD. Therefore, the following additional mitigation measures were analyzed and eliminated from further consideration:

- Reduction of training. The requirements for training have been developed through many years of iteration to ensure sailors achieve levels of readiness to ensure they are prepared to properly respond to the many contingencies that may occur during an actual mission. These training requirements are designed provide the experience needed to ensure sailors are properly prepared for operational success. There is no extra training built in to the plan, as this would not be an efficient use of the resources needed to support the training (e.g., fuel, time). Therefore, any reduction of training would not allow sailors to achieve satisfactory levels of readiness needed to accomplish their mission.

- Use of ramp-up to attempt to clear the range prior to the conduct of exercises. Ramp-up procedures, (slowly increasing the sound in the water to necessary levels), are not a viable alternative for training exercises because the ramp-up would alert opponents to the participants' presence. This affects the realism of training in that the target submarine would be able to detect the searching unit prior to themselves being detected, enabling them to take evasive measures. This would insert a significant anomaly to the training, affecting its realism and effectiveness. Though ramp-up procedures have been used in testing, the procedure is not effective in training sailors to react to tactical situations, as it provides an unrealistic advantage by alerting the target. Using these procedures would not allow the Navy to conduct realistic training, thus adversely impacting the effectiveness of the military readiness activity.

- Visual monitoring using third-party observers from air or surface platforms, in addition to the existing Navy-trained lookouts.
    - o The use of third-party observers would compromise security due to the requirement to provide advance notification of specific times/locations of Navy platforms.
    - o Reliance on the availability of third-party personnel would also impact training flexibility, thus adversely affecting training effectiveness.

o The presence of other aircraft in the vicinity of naval exercises would raise safety concerns for both the commercial observers and naval aircraft.

o Use of Navy observers is the most effective means to ensure quick and effective implementation of mitigation measures if marine species are spotted. A critical skill set of effective Navy training is communication. Navy lookouts are trained to act swiftly and decisively to ensure that appropriate actions are taken.

o Use of third-party observers is not necessary because Navy personnel are extensively trained in spotting items on or near the water surface. Navy spotters receive more hours of training, and use their spotting skills more frequently, than many third-party trained personnel.

o Crew members participating in training activities involving aerial assets have been specifically trained to detect objects in the water. The crew's ability to sight from both surface and aerial platforms provides excellent survey capabilities using the Navy's existing exercise assets.

o Security clearance issues would have to be overcome to allow non-Navy observers onboard exercise participants.

o Some training events will span one or more 24-hour periods, with activities underway continuously in that timeframe. It is not feasible to maintain non-Navy surveillance of these activities, given the number of non-Navy observers that would be required onboard.

o Surface ships having active mid-frequency sonar have limited berthing capacity. As exercise planning includes careful consideration of this limited capacity in the placement of exercise controllers, data collection personnel, and Afloat Training Group personnel on ships involved in the exercise. Inclusion of non-Navy observers onboard these ships would require that in some cases there would be no additional berthing space for essential Navy personnel required to fully evaluate and efficiently use the training opportunity to accomplish the exercise objectives.

o Contiguous ASW events may cover many hundreds of square miles. The number of civilian ships and/or aircraft required to monitor the area of these events would be considerable. It is, thus, not feasible to survey or monitor the large exercise areas in the time required ensuring these areas are devoid of marine mammals. In addition, marine mammals may move into or out of an area, if surveyed before an event, or an animal could move into an area after an exercise took place. Given that there are no adequate controls to account for these or other possibilities and there are no identified research objectives, there is no utility to performing either a before or an after the event survey of an exercise area.

o Survey during an event raises safety issues with multiple, slow civilian aircraft operating in the same airspace as military aircraft engaged in combat training activities. In addition, most of the training events take place far from land, limiting both the time available for civilian aircraft to be in the exercise area and presenting a concern should aircraft mechanical problems arise.

o Scheduling civilian vessels or aircraft to coincide with training events would impact training effectiveness, since exercise event timetables cannot be precisely

fixed and are instead based on the free-flow development of tactical situations. Waiting for civilian aircraft or vessels to complete surveys, refuel, or be on station would slow the unceasing progress of the exercise and impact the effectiveness of the military readiness activity.

- o Multiple simultaneous training events continue for extended periods. There are not enough qualified third-party personnel to accomplish the monitoring task.

- Reducing or securing power during the following conditions.

  - o Low-visibility / night training: ASW can require a significant amount of time to develop the "tactical picture," or an understanding of the battle space such as area searched or unsearched, identifying false contacts, understanding the water conditions, etc. Reducing or securing power in low-visibility conditions would affect a commander's ability to develop this tactical picture and would not provide realistic training.

  - o Strong surface duct: The complexity of ASW requires the most realistic training possible for the effectiveness and safety of the sailors. Reducing power in strong surface duct conditions would not provide this training realism because the unit would be operating differently than it would in a combat scenario, reducing training effectiveness and the crew's ability. Additionally, water conditions may change rapidly, resulting in continually changing mitigation requirements, resulting in a focus on mitigation versus training.

- Vessel speed: Establish and implement a set vessel speed.

  - o Navy personnel are required to use caution and operate at a slow, safe speed consistent with mission and safety. Ships and submarines need to be able to react to changing tactical situations in training as they would in actual combat. Placing arbitrary speed restrictions would not allow them to properly react to these situations, resulting in decreased training effectiveness and reduction the crew proficiency.

- Increasing power down and shut down zones:

  - o The current power down zones of 457 and 914 m (500 and 1,000 yd), as well as the 183 m (200 yd) shut down zone were developed to minimize exposing marine mammals to sound levels that could cause temporary threshold shift (TTS) or permanent threshold shift (PTS), levels that are supported by the scientific community. Implementation of the safety zones discussed above will prevent exposure to sound levels greater than 195 dB re 1μPa for animals sighted. The safety range the Navy has developed is also within a range sailors can realistically maintain situational awareness and achieve visually during most conditions at sea.

  - o Although the three action alternatives were developed using marine mammal density data and areas believed to provide habitat features conducive to marine mammals, not all such areas could be avoided. ASW requires large areas of ocean space to provide realistic and meaningful training to the sailors. These areas were considered to the maximum extent practicable while ensuring Navy's ability to properly train its forces in accordance with federal law. Avoiding any area that

has the potential for marine mammal populations is impractical and would impact the effectiveness of the military readiness activity.

- Using active sonar with output levels as low as possible consistent with mission requirements and use of active sonar only when necessary.

    o Operators of sonar equipment are always cognizant of the environmental variables affecting sound propagation. In this regard, the sonar equipment power levels are always set consistent with mission requirements.

    o Active sonar is only used when required by the mission since it has the potential to alert opposing forces to the sonar platform's presence. Passive sonar and all other sensors are used in concert with active sonar to the maximum extent practicable when available and when required by the mission.

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12 MINIMIZATION OF ADVERSE EFFECTS ON SUBSISTENCE USE

Based on the discussions in Chapter 8, there are no impacts on the availability of species or stocks for subsistence use.

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13 MONITORING AND REPORTING MEASURES

13.1 NWTRC Marine Species Monitoring Plan

The Navy is developing a Marine Species Monitoring Plan (MSMP) that provides recommendations for site-specific monitoring for MMPA and ESA listed species (primarily marine mammals) within the Northwest training Range Complex (NWTRC), including during training. The primary goals of monitoring are to evaluate trends in marine species distribution and abundance in order to assess potential population effects from Navy training activities and determine the effectiveness of the Navy's mitigation measures. The information gained from the monitoring will also allow the Navy to evaluate the models used to predict effects to marine mammals.

By using a combination of monitoring techniques or tools appropriate for the species of concern, type of Navy activities conducted, sea state conditions, and the size of the Range Complex, the detection, localization, and observation of marine mammals and sea turtles can be maximized. The following available monitoring techniques and tools are described in this monitoring plan for monitoring for range events (several days or weeks) and monitoring of population effects such as abundance and distribution (months or years):

- Visual Observations – Vessel-, Aerial- and Shore-based Surveys (for marine mammals and sea turtles) will provide data on population trends (abundance, distribution, and presence) and response of marine species to Navy training activities. Navy lookouts will also record observations of detected marine mammals from Navy ships during appropriate training and test events.

- Acoustic Monitoring – Passive Acoustic Monitoring possibly using towed hydrophone arrays, Autonomous Acoustic Recording buoys and U.S. Navy Instrument Acoustic Range (for marine mammals only) may provide presence/absence data on cryptic species that are difficult to detect visually (beaked whales and minke whales) that could address long term population trends and response to Navy training exercises.

- Tagging – Tagging marine mammals with instruments to measure their dive depth and duration, determine location and record the received level of natural and anthropogenic sounds.

- Additional Methods – Oceanographic Observations and Other Environmental Factors will be obtained during ship-based surveys and satellite remote sensing data. Oceanographic data is important factor that influences the abundance and distribution of prey items and therefore the distribution and movements of marine mammals.

The monitoring plan will be reviewed annually by Navy biologists to determine the effectiveness of the monitoring elements and to consider any new monitoring tools or techniques that may have become available.

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14 RESEARCH

The Navy provides a significant amount of funding and support to marine research. The agency provides nearly 18 million dollars annually to universities, research institutions, federal laboratories, private companies, and independent researchers around the world to study marine mammals. The U.S. Navy sponsors seventy percent of all U.S. research concerning the effects of human-generated sound on marine mammals and 50 percent of such research conducted worldwide. Major topics of Navy-supported research include the following:

- Better understanding of marine species distribution and important habitat areas,

- Developing methods to detect and monitor marine species before and during training,

- Understanding the effects of sound on marine mammals, sea turtles, fish, and birds, and

- Developing tools to model and estimate potential effects of sound.

This research is directly applicable to Fleet training activities, particularly with respect to the investigations of the potential effects of underwater noise sources on marine mammals and other protected species. Proposed training activities employ sonar and underwater explosives, which introduce sound into the marine environment.

The Marine Life Sciences Division of the Office of Naval Research currently coordinates six programs that examine the marine environment and are devoted solely to studying the effects of noise and/or the implementation of technology tools that will assist the Navy in studying and tracking marine mammals. The six programs are as follows:

- Environmental Consequences of Underwater Sound,

- Non-Auditory Biological Effects of Sound on Marine Mammals,

- Effects of Sound on the Marine Environment,

- Sensors and Models for Marine Environmental Monitoring,

- Effects of Sound on Hearing of Marine Animals, and

- Passive Acoustic Detection, Classification, and Tracking of Marine Mammals.

The Navy has also developed the technical reports referenced within this document, which include the Marine Resource Assessments and the Navy Operating Area Density Estimates (NODE) reports. Furthermore, research cruises by the National Marine Fisheries Service (NMFS) and by academic institutions have received funding from the U.S. Navy.

The Navy has sponsored several workshops to evaluate the current state of knowledge and potential for future acoustic monitoring of marine mammals. The workshops brought together acoustic experts and marine biologists from the Navy and other research organizations to present data and information on current acoustic monitoring research efforts and to evaluate the potential for incorporating similar technology and methods on instrumented ranges. However, acoustic detection, identification, localization, and tracking of individual animals still requires a significant amount of research effort to be considered a reliable method for marine mammal monitoring. The Navy supports research efforts on acoustic monitoring and will continue to investigate the feasibility of passive acoustics as a potential mitigation and monitoring tool.

Overall, the Navy will continue to fund ongoing marine mammal research, and is planning to coordinate long term monitoring/studies of marine mammals on various established ranges and operating areas. The Navy will continue to research and contribute to university/external research to improve the state of the science regarding marine species biology and acoustic effects. These efforts include mitigation and monitoring programs; data sharing with NMFS and via the literature for research and development efforts; and future research as described previously.

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