REQUEST FOR LETTER OF AUTHORIZATION FOR THE INCIDENTAL HARASSMENT OF MARINE MAMMALS RESULTING FROM NAVY RESEARCH, DEVELOPMENT, TEST, AND EVALUATION ACTIVITIES CONDUCTED WITHIN THE NAVSEA NUWC KEYPORT RANGE COMPLEX EXTENSION

FINAL

Submitted to:

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Acronyms and Abbreviations

3-D	3-dimensional
ASW	Anit-Submarine Warfare
AV	Autonomous Vehicle
BA	Biological Assessment
BE	Biological Evaluation
CFR	Code of Federal Regulations
CHESS	Chase Encirclement Stress Studies
CPUE	Catch per Unit Effort
CV	Coefficient of Variation
dB	decibel(s)
dB re 1 μPa@1 m	decibel(s) reference 1 micropascal at 1 meter
DBDBV	Digital Bathymetry Data Base Variable Resolution
DBRC	Dabob Bay Range Complex
DCASS	Directional command activated sonobuoy systems
DoC	Department of Commerce
DoN	Department of the Navy
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
EL	energy flux density level
EO	Executive Order
ESA	Endangered Species Act
ETP	Eastern Tropical Pacific
FOIA	Freedom of Information Act
FONSI	Finding of No Significant Impact
ft	foot/feet
GDEM	Generalized Digital Environmental Model
ha	hectare(s)
HFBL	High-Frequency Bottom Loss
HPA	hypothalamic-pituitary-adrenal
Hz	Hertz
IUCN	International Union for Conservation of Nature,
IWC	International Whaling Commission
kg	
kHz	kiloHertz
km	kilometer(s)
km^2	square kilometer
kph	kilometers per hour
lbs	pounds
LFA	Low Frequency Active
LFBL	Low Frequency Bottom Loss
LIDAR	laser imaging detection and ranging
LOA	Letter of Authorization
m	meter(s)
MFA	Mid-Frequency Active
mi	statute mile(s)
min	minute(s)
MMPA	Marine Mammal Protection Act
MOA	Military Operating Area
MRA	Marine Resource Assessment
MRTFB	Major Range Test Facility Base
msec	milliseconds
NAS	International Union for Conservation of Nature
NAVSEA	Naval Sea Systems Command

nm	nautical mile(s)
nm^2	square nautical mile(s)
NMFS	National Marine Fisheries Service
NMMTB	National Marine Mammal Tissue Bank
NOAA	National Oceanic and Atmospheric Administration
NOTMAR	Notice to Mariners
NPO	North Pacific Ocean
NRC	National Research Council
NUWC Keyport	Naval Undersea Warfare Center, Keyport
OAML	Ocean Atmosphere Master Library
OCNMS	Olympic Coast National Marine Sanctuary
OEIS	Overseas Environmental Impact Statement
OPAREA	Operations Area
OPNAVINST	Chief of Naval Operations Instruction
PCB	polychlorinated biphenyl
PTS	Permanent Threshold Shift
QUTR	Quinault Underwater Tracking Range
RDT&E	Research, Development, Test, and Evaluation
rms	root mean square
ROI	Region of Influence
ROP	Range Operating Policies and Procedures
ROV	Remotely Operated Vehicle
s	second
SD	standard deviation
SNS	sympathetic nervous system
sp.	species
SPL	Sound Pressure Level
SUBASE	Submarine Base
TL	Transmission Loss
TTS	Temporary Threshold Shift
TTS2	TTS 2 minutes post exposure
UME	Unusual Mortality Event
μPa	micro Pascal(s)
USC	United States Code
UQC	Underwater mobile sound communications
USWEX	Undersea Warfare Exercise
UUV	Unmanned Undersea Vehicle
W	Warning Area
ZOI	Zone of Influence

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 incidental to the research, development, test, and evaluation (RDT&E) activities within the NAVSEA NUWC Keyport Range Complex Extension for the period September 2009 through April 2014, as permitted by the Marine Mammal Protection Act (MMPA) of 1972, as amended. While there are no non-acoustical impacts, the RDT&E activities may expose certain marine mammals that may be present within the NAVSEA NUWC Keyport Range Complex to sound from mid- and high-frequency acoustic sources.

Mid- and high-frequency acoustic sources and other acoustic sources are used by NUWC Keyport for many purposes including underwater communication, mapping the seabed, torpedo countermeasures, and detecting submarines, inert mines, and obstacles. Potential acoustic sources used during test and evaluation activities within the NAVSEA NUWC Keyport Range Complex were examined with regard to their operational characteristics. Based on this analysis, eight acoustic sources with source levels no greater than 238 dB re 1 µPa@1 m were selected for marine mammal acoustic effects analysis for potential permanent threshold shift (PTS) and temporary threshold shift (TTS) impacts and determine potential behavioral exposures (Tables 6-23, 6-24 and 6-25). This is a representative subset of the types of acoustic sources that would be used on the NAVSEA NUWC Keyport Range Complex.

The potential acoustic exposures outlined in Chapter 6 represent the estimated annual number of exposures to marine mammals that may result in incidental harassment of marine mammals during Navy RDT&E activities in the NAVSEA NUWC Keyport Range Complex Extension after implementation of Range Operating Procedures (ROP). Based on the regulatory framework established under the MMPA, the Navy has worked with the National Marine Fisheries Service (NMFS) to develop criteria and methodology for evaluating when sound exposure might constitute incidental harassment. The MMPA defines two types of harassment, Level A (potential injury) and Level B (disturbance), evaluated here as follows:

- 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 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.
- Level B: 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 Level B harassment for cetaceans. EL thresholds for temporary physiological effects in pinnipeds are species-specific and are presented in Table ES-1 below.
- Level B: 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) to behaviorally disturb marine mammals. Based on comments received on prior Navy actions, a risk-function is used to estimate 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.

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

Level B harassment in the context of military readiness activities is defined 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 Level B harassment is presented without consideration of mitigation measures. In addition, the assessment of whether temporary physiological effects or behavioral responses may cause behavioral patterns to be abandoned or significantly altered is considered in the context of an analytical framework for mid- and high-frequency acoustic sources. This framework acknowledges that only a subset of exposures are likely to result in Level B harassment, and that multiple exposures of the same individual 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 Level B harassment.

The conservative analysis used to estimate the maximum number of marine mammals per year that could be exposed annually by Navy RDT&E activities within the NAVSEA NUWC Keyport Range Complex and proposed extensions will estimate the potential effects. For example the analysis assumes that the entire population of harbor porpoise within the QUTR Range Site is exposed for each day of operation. The potential annual exposures for all three range sites after implementation of ROP (Table 6-26) from acoustic sources using the Risk Function is 14,961 and TTS is 2,062 (Level B harassment) for a total of 17,023 annual exposures. The modeling indicates no exposures for pinnipeds that exceed the temporary TTS threshold. The modeling indicates that sound levels that may cause a permanent threshold shift (Level A harassment) are not likely to reach marine mammals.

The numbers of marine mammals predicted from modeling to be exposed are presented without taking into consideration the use of ROP. The ROP, outlined in Chapter 11, substantially decreases the number of animals potentially exposed and affected. ROPs that would specifically reduce the potential exposures are those listed under ROP 6-4 and include but are not limited to utilization of marine mammal observers on board ships during RDT&E activities, the creation of an exclusion zone around RDT&E activities (within which surveillance for marine mammals is actively conducted), and the cessation of RDT&E activities in the presences of marine mammals. The potential exposures outlined in Chapter 6 represent the expected number of cetaceans and pinnipeds that could be affected from range activities after implementation of ROP.

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 indicates that blue whales, fin whales, humpback whales, north Pacific right whales, sei whales, sperm whales and resident killer whales may be exposed to sound levels that may affect these species. The ongoing ESA Section 7 consultation will examine the anticipated responses and any associated fitness consequences for these ESA-listed species to determine if MMPA incidental harassment authorization is required for a certain subset of the predicted exposures. However, given implementation of ROP, it is unlikely that RDT&E activities would adversely affect these species. Based on the potential for physiological and behavioral disturbance, the interpretation of the modeling indicates that only Level B harassment is anticipated for all marine mammal species in the NAVSEA NUWC Keyport Range Complex Extension. 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.

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1 DESCRIPTION OF ACTIVITIES

This Chapter describes the mission activities conducted within the Naval Sea Systems Command (NAVSEA) Naval Undersea Warfare Center (NUWC) Keyport Range Complex and the associated proposed extensions that could result in Level B harassment and possibly Level A harassment, under the Marine Mammal Protection Act (MMPA) of 1972, as amended in 1994. Typical activities conducted in the NAVSEA NUWC Keyport Range Complex on the three existing range sites primarily support undersea warfare RDT&E program requirements, but they also support general equipment test and military personnel training needs, including Fleet activities. These activities involve mid- and high-frequency acoustic sources with the potential to affect marine mammals that may be present within the NAVSEA NUWC Keyport Range Complex Extension.

1.1 Background

The Department of the Navy (Navy) proposes to extend the NAVSEA NUWC Keyport Range Complex in Washington State. The NAVSEA NUWC Keyport Range Complex Extension has the infrastructure to support RDT&E activities. Centrally located within the Northwest Range Complex in Washington State, the NAVSEA NUWC Keyport Range Complex Extension has extensive existing range assets and training capabilities. The NAVSEA NUWC Keyport Range Complex Extension is composed of Keyport Range Site, Dabob Bay Range Complex (DBRC) Site, and Quinault Underwater Tracking Range (QUTR) Site (Figure 1-1).

The Navy needs to extend the operating areas within the NAVSEA NUWC Keyport Range Complex to provide marine environments that meet evolving operational requirements for manned and unmanned vehicle testing. NUWC Keyport has historically provided facilities for testing torpedoes, submarine readiness, diver training, and similar systems. This Letter of Authorization (LOA) addresses potential effects to marine mammals associated with the Proposed Action. The goal of the Proposed Action is to extend the operational areas of each range site. Extending the Range Complex operating areas outside existing range boundaries will allow the Navy to support existing and future range activities including evolving manned and unmanned vehicle program needs in multiple marine environments. With the proposed extension of the Keyport and QUTR range sites, the range sites could support more activities, which include increases in the numbers of tests and days of testing. No additional operational tempo is proposed for the DBRC Site. Existing and evolving range activities analyzed in this LOA include testing, training, and evaluation of system capabilities such as guidance, control, and sensor accuracy of manned and unmanned vehicles in multiple marine environments (e.g., differing depths, salinity levels, temperatures, sea states, etc.). This document analyzes activities that may affect marine mammals that are present in the NAVSEA NUWC Keyport Range Complex Extension.

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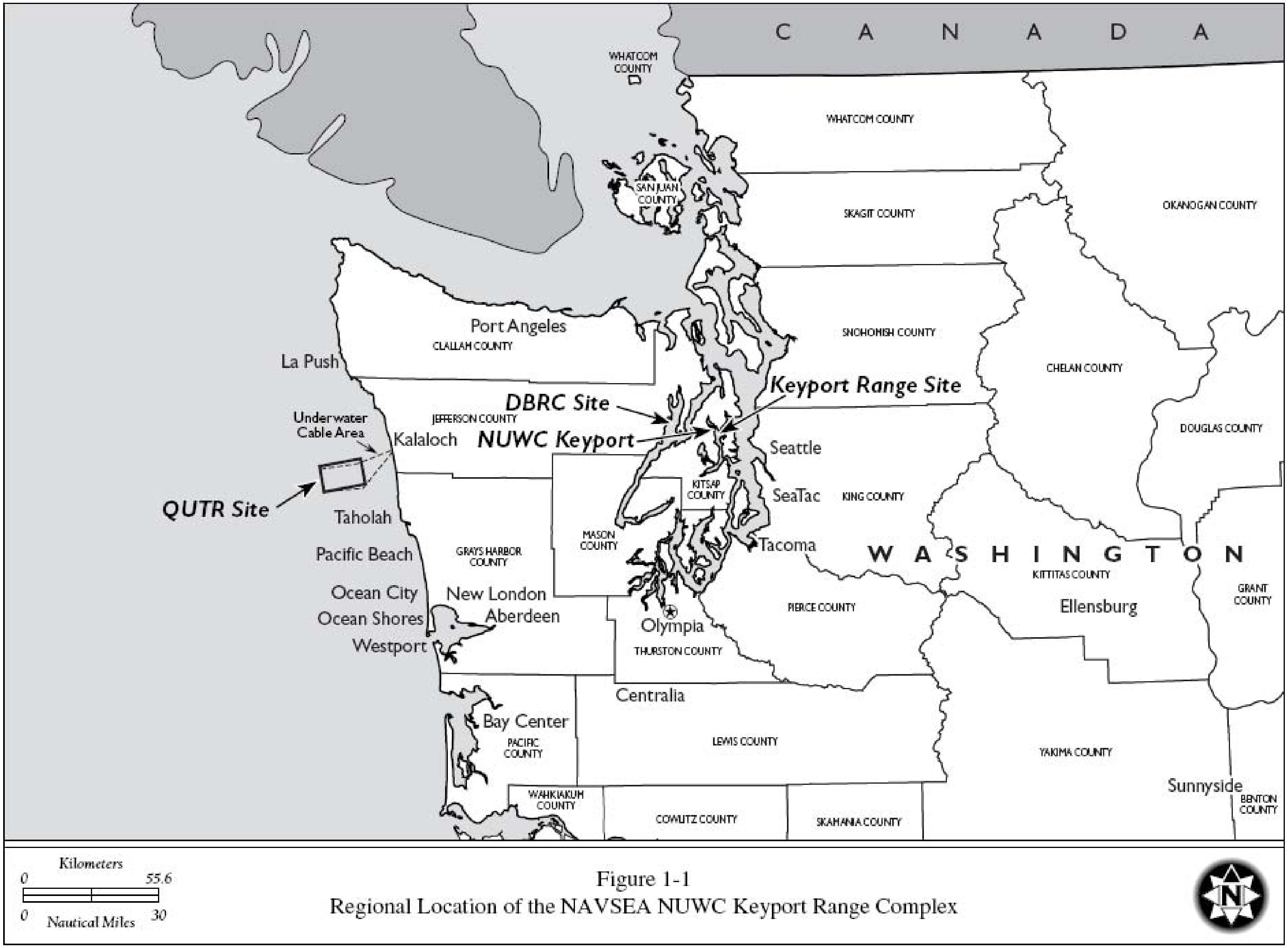

Figure 1-1: Regional Location of the NAVSEA NUWC Keyport Range Complex

Activities conducted at the various range sites may be related operationally in that certain tests are run interdependently and are used in tandem. However, each test is conducted solely at a single range site location, and each site is independently monitored for safety and operational purposes.

The range extension is necessary to provide adequate testing area and volume (i.e., surface area and water depth) in multiple marine environments. The extension enables the NUWC Keyport to fulfill its mission of providing test and evaluation services in both surrogate and simulated war-fighting environments for emerging manned and unmanned vehicle program activities. Within the NAVSEA NUWC Keyport Range Complex Extension, the NUWC Keyport activities include testing, training, and evaluation of systems capabilities such as guidance, control, and sensor accuracy of manned and unmanned vehicles in multiple marine environments (e.g., differing depths, salinity levels, temperatures, sea states, etc.).

NUWC Keyport consists of 340 acres (138 hectares [ha]) on the shores of Liberty Bay and Port Orchard Reach (a.k.a. Port Orchard Narrows), and is located adjacent to the town of Keyport, due west of Seattle. NUWC Keyport, a part of NAVSEA, is the center for integrated undersea warfare systems dependability, integrated mine and undersea warfare supportability, and undersea vehicle maintenance and engineering. It provides test and evaluation, in-service engineering, maintenance, Fleet readiness, and industrial-based support for undersea warfare systems, including RDT&E of torpedoes, unmanned vehicles, sensors, targets, countermeasure systems, and acoustic systems.

As stated above, acoustic sources are used by NUWC Keyport for many purposes including underwater communication, mapping the seabed, torpedo countermeasures, and detecting submarines, inert mines, and obstacles. Potential acoustic sources used during test and evaluation activities within the NAVSEA NUWC Keyport Range Complex were examined with regard to their operational characteristics. Generally, systems with an operating frequency greater than 150 kHz were not analyzed, as these signals attenuate rapidly resulting in very short propagation distances. Similarly, systems with acoustic source levels below 205 dB re 1 µPa @ 1 m were not considered because, at this source level, a 1-second ping would attenuate below the threshold for behavioral effects on marine mammals at a distance of 5.6 m (18 ft) from the source. Systems above this source level were included in the analysis. Based on this, eight representative acoustic sources with source levels no greater than 233 dB re 1 µPa@1 m were selected for marine mammal acoustic effects analysis for potential permanent threshold shift (PTS) and temporary threshold shift (TTS) impacts and determine potential behavioral exposures (Table 1-1). This is a subset of the types of acoustic sources that would be used on the NAVSEA NUWC Keyport Range Complex. Parameters were set up based on frequencies and output levels to ensure there was a variety of types of acoustic sources to consider.

Table 1-1: Representative Acoustic Sources within the NAVSEA NUWC Keyport Range Complex Used for Marine Mammal Acoustic Effects Analysis

Acoustic Source	*Frequency (kHz)*	*Source Level (dB re 1 µPa @ 1 m)*
Subbottom Profiler	4.5	207
UUV 1	15	205
UUV Acoustic Modem	10	186
UUV 2	150	220
Range Target	5	233
Test Vehicle 1	20	233
Test Vehicle 2	25	230
Test Vehicle 3	30	233

Keyport Range Site

Located adjacent to NUWC Keyport, this range provides approximately 1.5 square nautical miles (nm^2) (5.1 square kilometers [km^2]) of shallow underwater testing, including in-shore shallow water sites and a shallow lagoon to support integrated undersea warfare systems and vehicle maintenance and engineering activities (Figures 1-2 and 1-3). The Navy has conducted underwater testing at the Keyport Range Site since 1914. Underwater tracking of test activities is accomplished by using temporary or portable range equipment. The range is currently used an average of 6 times per year for vehicle testing and a variety of boat and diver training activities, each lasting 1–30 days. There may be several activities in 1 day. The range site also supports: 1) detection, classification, and localization test objectives and 2) magnetics measurement programs. Explosive warheads are not placed on test units or tested within the Keyport Range Site. The Keyport Range Site is charted as a Restricted Area on NOAA Navigation Chart 18446 (NOAA 1998).

Existing NEPA documentation includes two EAs and FONSIs completed in 2000 and 2003. The removal and replacement of NUWC Keyport's pier was addressed in the NUWC Keyport Pier EA, which resulted in a FONSI in 2000 (NUWC Keyport 2000). The new pier is in the proposed extended area. The Autonomous Underwater Vehicle (AUV) Fest EA resulted in a FONSI in 2003 (Department of the Navy [DoN] 2003). This EA was an analysis of using the proposed extended area specifically for UUV testing and this EIS/OEIS incorporates most of the analysis associated with that EA. In this EIS/OEIS, the addition of activities associated with Fleet cold water training and the acoustic test facility have been added for the purposes of analysis in this EIS/OEIS. There are no explosive warheads tested or placed on test units.

DBRC Site

The Navy has conducted underwater testing at the DBRC Site since 1956, beginning with a control center at Whitney Point. The control center was subsequently moved to Zelatched Point. Currently, the DBRC Site assets include the Dabob Bay Military Operating Area (MOA), the Hood Canal North and South MOAs adjacent to Submarine Base (SUBASE) Bangor, and the Connecting Waters (Figures 1-2 and 1-4). The DBRC Site is the Navy's premier location within the U.S. for RDT&E of underwater systems such as torpedoes, countermeasures, targets, and ship systems. Primary activities at the DBRC Site support proofing of underwater systems, research and development test support, and Fleet training and tactical evaluations involving aircraft, submarines, and surface ships. Tests and evaluations of underwater systems, from the first prototype and pre-production stages up through Fleet activities (inception to deployment), ensure reliability and availability of underwater systems and their Fleet components. As with the Keyport Range Site, there are no explosive warheads tested or placed on test units.

The DBRC Site also supports acoustic/magnetic measurement programs. These programs include underwater vehicle/ship noise/magnetic signature recording, radiated sound investigations, and other acoustic evaluations. In the course of these activities, various combinations of aircraft, submarines, and surface ships are used as launch platforms. Test equipment may also be launched or deployed from shore off a pier or placed in the water by hand. NUWC Keyport currently conducts activities within four underwater testing areas in the DBRC Site. These areas are:

- Dabob Bay MOA – – a deep-water range in Jefferson County approximately 14.5 nm^2 (49.9 km^2) in size. The acoustic tracking space within the range is approximately 7.3 by 1.3 nm (13.5 by 2.4 km) (9.5 nm^2 [32.4 km^2]) with a maximum depth of 600 ft (183 m). The Dabob Bay MOA is the principal range and the only component of the DBRC Site with extensive acoustic monitoring instrumentation installed on the seafloor, allowing for object tracking, communications, passive sensing, and target simulation. Because of its importance the Dabob Bay MOA has been designated a DoD Major Range Test Facility Base (MRTFB). MRTFB ranges are recognized as critical assets to national defense. Activities within the Dabob Bay MOA are supported by land-based facilities at Zelatched Point. The Zelatched Point area occupies 28 acres (11 ha) of land owned by the Navy overlooking Dabob Bay. The pier at Zelatched Point, which was historically used for float planes and range craft, will be refurbished in the future. This is outside the scope of this EIS/OEIS analysis and additional NEPA documentation will be prepared to address its replacement. There is also a landing pad at Zelatched Point to support helicopter activities.

- Hood Canal MOAs – There are two deep-water operating areas adjacent to SUBASE Bangor in Hood Canal; Hood Canal MOA South, which is approximately 4.5 nm^2 (15.4 km^2) in size, and Hood Canal MOA North, which is approximately 7.9 nm^2 (27.0 km^2) in size. Both areas have an average depth of 200 ft (61 m). The Hood Canal MOAs are used for vessel sensor accuracy tests and launch and recovery of test systems where tracking is optional.

- Connecting Waters – the portion of the Hood Canal that connects the Dabob Bay MOA with the Hood Canal MOAs (Figure 1-3). The shortest distance between the Dabob Bay MOA and Hood Canal MOA South by water is approximately 5.8 nm^2 (19.8 km^2). Water depth in the Connecting Waters is typically greater than 300 ft (91 m).

The DBRC MOA and the Hood Canal MOAs are charted as Naval Operating Areas on NOAA Navigation Chart 18458 (NOAA 1997). Existing NEPA documentation includes an environmental assessment and FONSI in 2002. It describes the current DBRC location and the current activities.

QUTR Site

The Navy has conducted underwater testing at the QUTR Site since 1981 and maintains a control center at the Kalaloch Ranger Station. As at the other range sites, no explosive warheads are used at the QUTR Site. The QUTR Site is a rectangular-shaped test area of about 48.3 nm^2 (165.5 km^2), located approximately 6.5 nm (12 km) off the Pacific Coast at Kalaloch, Washington (Figure 1-4). It lies within the boundaries of the Olympic Coast National Marine Sanctuary (OCNMS).

The QUTR Site is instrumented to track surface vessels, submarines, and various undersea vehicles. Bottom sensors are permanently mounted on the sea floor for tracking and are maintained and configured by the Navy. The sensors are connected to the shore via cables, which extend under the beach to the bluffs and end at a Navy trailer in Kalaloch (National Park Service [NPS] property). In addition, portable range equipment may be set up prior to conducting various activities on the range and removed after it is no longer needed. All communications are sent back to NUWC Keyport for monitoring.

As was mentioned above, this range underlies a small portion (W-237A) of the larger airspace unit W-237. This airspace complex comprises the northern portion of the Pacific Northwest Ocean Surface/Subsurface Operating Area (OPAREA), NOAA chart number 18500 (NOAA 2006). Activities in this airspace are scheduled and coordinated with Naval Air Station (NAS) Whidbey Island and Commander Submarine Force, U.S. Pacific Fleet (COMSUBPAC). Navy activity within W-237A has been addressed in the NOAA OCNMS EIS for the 1993 establishment of the OCNMS. The LOA evaluates Navy activities in the OCNMS and includes activities related to the QUTR instrumented area and its findings incorporated by reference.

1.2 Acoustic Sources Commonly Used within the NAVSEA Keyport Range Complex Extension

1.2.1 Active Acoustic Devices

Weapon systems, targets, and other autonomous vehicles (AVs) may involve a variety of active and passive acoustic systems. Active systems are those that emit acoustic energy or sound into the water. Passive acoustic systems do not generate acoustic energy in the water but are used to listen for sound in the water. NAVSEA NUWC Keyport uses a number of passive acoustic measurement systems including a bottom moored array and various surface deployed arrays. The instrumented portions of the range sites have tracking arrays mounted on the sea floor to detect sound. The permanently deployed tracking arrays provide 3-D tracking capability at the DBRC and QUTR sites. Additionally, 3-D tracking can be accomplished by using portable tracking hardware in a pattern for any location. The data are processed and one of the results is the display of speed and location of each tracked item. Most test vehicles are instrumented with active acoustic sources to track real-time speed, location and recovery or retrieval at the end of activities.

1.2.2 Acoustic Impacts

Table 1-2 lists the primary active acoustic sources used within the NAVSEA NUWC Keyport Range Complex shows the frequency bands of these acoustic sources. In this document, low frequency is defined as below 1 kiloHertz (kHz), mid frequency is defined as between 1 kHz and 10 kHz, and high frequency is defined as above 10 kHz.

Table 1-2: Primary Acoustic Sources Commonly Used within the NAVSEA NUWC Keyport Range Complex

Sources	Frequency* (kHz)	Maximum Source Level (dB re 1 µPa @ 1 m)
Sonars		
General range tracking (at Keyport Range Site)	10 - 100	195
General range tracking (at DBRC and QUTR Sites)	10 - 100	203
UUV tracking	10 - 100	195
Torpedoes	10 - 100	233
Range targets and special tests (at Keyport Range Site)	5 - 100	195
Range targets and special tests (at DBRC and QUTR Sites)	5 - 100	238
Special sonars (e.g., UUV payload)	100 – 2,500	235
Fleet aircraft—active sonobuoys and helo-dipping sonars	2 - 20	225
Side-scan	100 - 700	235
Other Acoustic Sources		
Acoustic modems	10 - 300	210
Target simulator	0.1 - 10	170
Aid to navigation (range equipment)	70 - 80	210
Sub-bottom profiler	2 - 7	210
	35 - 45	220
Engine noise (surface vessels, submarines, torpedoes, UUVs)	0.05 – 10	170

1.2.2.1 General Range Tracking

General range tracking on the instrumented ranges and portable range sites have active output in narrow frequency bands. Operating frequencies are 10 to 100 kHz. At the Keyport Range Site, the sound pressure level (SPL) at the source (source level) is less than 195 decibels reference 1 microPascal at 1 meter (dB re 1 µPa @ 1 m). At the DBRC and QUTR sites, the source level for general range tracking is less than 203 dB re 1 µPa @ 1 m. Range pingers are active acoustic devices that allow each of the in-water platforms on the range (e.g., ships, submarines, target simulators, and exercise torpedoes) to be tracked by the NAVSEA NUWC Keyport Range Complex Extension hydrophones. In addition to passively tracking the pinger signal from each range participant, the range transducer nodes also are capable of transmitting acoustic signals for a limited set of functions. These functions include submarine warning signals, acoustic commands to submarine target simulators (acoustic command link), and occasional voice or data communications (received by participating ships and submarines on range). Based on the operational characteristics (source output level and/or frequency) of these acoustic sources, the potential to affect marine mammals is unlikely, and therefore they were not modeled for this analysis (Lazauski, et. al. 1999; NOAA 2002).

1.2.2.2 UUV Tracking Systems

UUV tracking systems operate at frequencies of 10 to 100 kHz with source levels less than 195 dB re 1 µPa @ 1 m at all range sites.

1.2.2.3 Torpedo Sonars

Torpedo sonars are used for several purposes including detection, classification, and location and vary in frequency from 10 to 100 kHz. The source level of a torpedo sonar is generally less than 233 dB re 1 µPa @ 1 m. Torpedoes are the primary 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. Potential impacts from the use of torpedoes on the range areas were analyzed in the NAVSEA NUWC Keyport Range Complex Extension Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS).

1.2.2.4 Range Targets and Special Tests

Range targets and special test systems are within the 5 to 100 kHz frequency range at the Keyport Range Site with a source level of less than 195 dB re 1 µPa @ 1 m. At the DBRC and QUTR sites, the source level is less than 238 dB re 1 µPa @ 1 m.

1.2.2.5 Special Sonars

Special sonars can be carried as a payload on a UUV, suspended from a range craft, or set on or above the sea floor. These can vary widely from 100 kHz to a very high frequency of 2,500 kHz for very short range detection and classification. The source level of these acoustic sources are less than 235 dB re 1 µPa @ 1 m.

1.2.2.6 Sonobuoys and Helicopter Dipping Sonar

Aircraft sonar systems that would operate in the NAVSEA NUWC Keyport Range Complex Extension include sonobuoys and dipping sonar. Sonobuoys and helicopter dipping sonars are deployed from Fleet aircraft and operate at frequencies of 2 to 20 kHz with source levels of less than 225 dB re 1 µPa @ 1 m. Dipping sonars are active or passive devices that are lowered on cable by helicopters or surface vessels to detect or maintain contact with underwater targets. Sonobuoys may be deployed by maritime patrol aircraft or helicopters; dipping sonars are used by carrier-based helicopters. A sonobuoy is an expendable device used by aircraft for the detection of underwater acoustic energy and for conducting vertical water column temperature measurements. Most sonobuoys are passive, but some can generate active acoustic signals, as well as listen passively. During RDT&E, these systems active modes are only used briefly for localization of contacts and are not used in primary search capacity. Because active mode dipping sonar use is very brief, it is extremely unlikely that its use would have any effect on marine mammals. However, the AN/AQS-22 dipping sonar was modeled based on estimated use during RDT&E within the NAVSEA NUWC Keyport Range Complex Extension.

1.2.2.7 Side Scan Sonar

Side scan sonar is used for mapping, detection, classification, and localization of items on the sea floor such as cabling, shipwrecks, and inert mine shapes. It is high frequency, typically 100 to 700 kHz, using multiple frequencies at one time with a very directional focus. Source levels are less than 235 dB re 1 µPa @ 1 m. Side-scan and multibeam sonar systems are towed or mounted on a test vehicle or ship.

1.2.2.8 Other Acoustic Sources

Other acoustic sources include acoustic modems, targets, aids to navigation, subbottom profilers, engine noise, countermeasures, etc. which uses few pulses from 10 to 300 kHz at source levels less than 220 dB. An acoustic modem is a communication device that transmits an acoustically encoded signal from a source to a receiver. Acoustic modems emit a few pulses from 10 to 300 kHz at source levels less than 210 dB re 1 µPa@1 m. Target simulators operate at frequencies of 100 hertz (Hz) (0.1 kHz) to 10 kHz at source levels of less than 170 dB re 1 µPa@1 m. Aids to navigation transmit location data from ship to shore and back to ship so the crew can have real-time detailed location information. This is typical of the range equipment used in support of testing. New aids to navigation can also be deployed and tested using 70–80 kHz at source levels less than 210 dB re 1 µPa@1 m. Subbottom profilers are often commercial off-the-shelf sonars used to determine characteristics of the sea bottom and subbottom such as mud above bedrock or other rocky substrate. These operate at 2–7 kHz at source levels less than 210 dB re 1 µPa@1 m, and 35–45 kHz at less than 220 dB re 1 µPa@1 m. There are many sources of engine noise including but not limited to surface vessels, submarines, torpedoes, and other UUVs. The acoustic energy is usually from 50 Hz to 10 kHz at source levels less than 150–170 dB re 1 µPa@1 m. Targets, both mobile and stationery, may simulate engine noise at these same frequencies.

1.2.3 Non-Acoustic Effects

1.2.3.1 Magnetic Sensors

A magnetic sensor may be used to sense the magnetic field of an object such as a surface vessel, a submarine, or a buried target. Magnetic sensors may be part of a UUV payload or they may be stationary on the sea floor.

1.2.3.2 Biologic Sensors

Biologic sensors have been used historically to determine marine characteristics such as conductivity, temperature, and pressure of water to determine sound velocity in water. This provides information about how sound will travel through the water. These sensors can be deployed over the side from a surface craft, suspended in water, or carried on a UUV.

1.2.3.3 LIDAR

Laser imaging detection and ranging (LIDAR) is used to measure distance, speed, rotation, and chemical composition and concentration of remote solid objects such as a ship, or diffuse objects such as a smoke plume or cloud. LIDAR uses the same principle as radar.

Because the human eye is more sensitive to laser radiation than either the cetacean or pinnipeds eye, LIDARs that currently meet human laser safety standards are expected to have no harmful effect on the eyes of marine mammals (Zorn et al. 1998). In addition, the likelihood that a LIDAR's beam would directly contact a marine mammal eye is considered extremely remote given the movement of marine mammals underwater and at the surface. Therefore, there would be no impacts to marine mammals due to the use of LIDAR with implementation of the proposed action within the proposed NAVSEA NUWC Keyport Range Complex extensions.

1.2.3.4 Inert Mine Hunting & Inert Mine Clearing Exercises

Associated with testing, a series of inert mine shapes are set out in a uniform or random pattern to test the detection, classification and localization capability of the system under test. They are made from plastic, metal, and concrete and vary in shape. For example, an inert mine shape can measure about 10 by 1.75 ft (3 by 0.5 m) and weigh about 800 lbs (362 kg). Inert mine shapes either sit on the bottom or are tethered by an anchor to the bottom at various depths. Inert mine shapes can be placed approximately 200-300 yards (183-274 m) apart using a support craft and remain on the bottom until they need to be removed. For example a concrete clump can be put on the bottom. It may be initially identified as a possible inert mine, but as the sensor becomes more sophisticated it will mark the clump as a non-mine (inert) and move on to locate other more probable inert mine shapes. All major components of all inert mine systems used as 'targets' for inert mine hunting systems are removed within 2 years. Therefore, there is little potential for this to cause adverse impacts on marine mammals.

The potential for direct physical contact between a marine mammal and an inert mine shape is extremely low given the low probability of occurrence of a marine mammal in the area and the unlikely potential that a marine mammal would hit a stationary item on the bottom. It is expected that any marine mammal encountering an inert mine shape would simply avoid it much as it would avoid a rocky outcrop along the sea floor. Therefore, there would be no adverse impacts to marine mammals and no takes under MMPA due to the placement and use of inert mine shapes with implementation of the proposed action within the proposed NAVSEA NUWC Keyport Range Complex extensions.

1.2.3.5 Collisions

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). NUWC Keyport has range operating procedures (ROP) in place to reduce the potential for collisions with marine mammals at the surface or underwater (refer to Sections 11). Surveys for marine mammals are conducted prior to each test, and tests are postponed or halted if a cetacean is observed on range or within established exclusion zones. For cetaceans the exclusion zones must be at least as large as the area in which the test vehicle may operate in and must extend at least 1,000 yards (914 m) from the intended track of the test vehicle. For pinnipeds, the exclusion zone extends out 100 yards (91 m) from the intended track of the test vehicle (for cetaceans and pinnipeds are established prior to an in-water exercise (NUWC Keyport 2004). In addition, NMFS recommends that vessels not intentionally approach within 100 yards (91 m) of marine mammals. Naval vessels and aircraft, including all helicopters, under the control of NUWC Keyport shall comply with this recommendation. Vessels are expected to implement actions, where feasible, to avoid interactions with marine mammals, including maneuvering away from the marine mammal or slowing the vessel. However, during reduced visibility conditions (i.e., fog, high sea state, and darkness) detecting marine mammals requires more diligence. Range vessels also follow prescribed safe navigation procedures in accordance with the Nautical Rules of the Road, including slowing, sounding fog signals, and adding additional lookouts to minimize the risk of collision with other vessels. Historically there has never been a reported vessel strike of a marine mammal within the NAVSEA NUWC Keyport Range Complex including periods of reduced visibility. A collision between a vessel and a marine mammal is considered extremely unlikely.

1.2.3.6 Torpedo Guidance Wire

The potential entanglement impact of torpedo control wires on marine mammals is very low. The control wire is very thin (approximately 0.02 inch) and has a relatively low breaking strength. Even with the exception of a chance encounter with the control wire while it was sinking to the sea floor (at an estimated rate of 0.5 ft per second), a marine mammal would not be vulnerable to entanglement given the low breaking strength.

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 catenary droop (DoN, 1996). When the wire is released 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 literature (DoN, 1996). The Navy, therefore, believes the potential for any harm or harassment to these species is extremely low.

1.2.4 Summary

Based on the foregoing, the following activities will not be carried forward in this LOA:

- General range tracking
- Acoustic countermeasures
- Underwater mobile sound communications (UQC)

- Mobile target emissions
- Directional command activated sonobuoy systems (DCASS)
- Engine noise
- Magnetic or Biological sensors
- LIDAR
- Expendable materials
- Collision

1.3 Proposed Action and Alternatives

The Navy proposes to extend the NAVSEA NUWC Keyport Range Complex in Washington State. The Proposed Action would provide additional operating space outside the existing operational areas to support existing and evolving range activities by NUWC Keyport. The scope of the Proposed Action includes only those activities scheduled and coordinated by NUWC Keyport. Other military activities currently occur within these areas (e.g., W-237A and DBRC Site are used for a variety of military activities outside of NUWC Keyport control). The exposure numbers in this LOA are based on the Preferred Alternative which is also the most conservative approach.

Under the No-Action Alternative, current activities would continue to be conducted on all three range sites and would continue to fit within the existing range dimensions currently established for the NAVSEA NUWC Keyport Range Complex. Annual activities broken out by activity type are shown in Table 1-3.

Currently, NUWC Keyport schedules the Keyport Range Site to be used an average of 55 days/year, the DBRC Site an average of 200 days/year, and the QUTR Site an average of 14 days/year of offshore use and minimally for surf-zone activities (Table 2-1).

Table 1-3: Existing Annual NAVSEA NUWC Keyport Range Complex Activities

		*Current Estimated Number of Activities/Year**		
Range Activity	*Platform/Systems Used*	*Keyport Range Site*	*DBRC Site*	*QUTR Site*
Test Vehicle Propulsion	Thermal propulsion systems	0	130	20
	Electric/Chemical propulsion systems	45	140	10
Other Testing Systems and Activities	Submarine testing	0	45	10
	Inert mine detection, classification and localization	5	20	5
	Non-Navy testing	5	5	5
	Acoustic & non-acoustic sensors (e.g., magnetic array, oxygen)	20	10	5
	Countermeasure test	5	50	5
	Impact testing	0	10	5
	Static in-water testing	10	10	5
	UUV test	45	120	20
Fleet Activities (excluding RDT&E)	Surface ship activities	1	10	10
	Aircraft activities	0	10	10
	Submarine activities	0	30	30
	Diver activities	45	5	10
Deployment Systems (RDT&E)	Range support vessels:			
	Surface launch craft	35	180	30
	Special purpose barges	25	75	0
	Fleet vessels	15	20	20
	Aircraft (rotary and fixed wing)	0	10	20
	Shore and pier	45	30	0

* There may be several activities in 1 day. These numbers provide an estimate of types of range activities over the year.

1.3.1 Current Keyport Range Site Activities

Table 1-3 lists the varied test and evaluation activities that currently occur at the Keyport Range Site in a typical year. Figure 1-5 illustrates an example scenario within the existing range site. The scenario consists of a combined shallow-water target field evaluation and personnel training using a UUV within existing range boundaries. A tracking system may be deployed in each test area for tracking the UUV. In this example scenario, the tracking system operates at a frequency of 75 kHz and a source level of less than 195 dB re 1 μPa @ 1 m. The primary objective is to demonstrate operational capabilities by conducting tests on a shallow-water target field. Secondary objectives are to test the UUV launch method and provide training opportunities for Navy personnel. The UUV is deployed from the NUWC Keyport Pier using a pier-side crane, and retrieval occurs using a small boat, divers, and pier-side crane; target shapes are positioned prior to, and recovered subsequent to, the test activity. The estimated time for the test, including set up and retrieval, is 3–6 hours. The combination of the following characteristics provide a unique testing environment at the Keyport Range Site; shallow depth (shore to 90 ft [27 m]), varying topography, shore-to-shore surveillance, shore facilities, and realistic navigational hazards (e.g., boat traffic).

1.3.2 Current DBRC Site Activities

Table 1-3 lists the current annual activities conducted at the DBRC Site. An example scenario within the existing range site is shown in Figure 1-6. The primary objective under this example scenario is a 72-hour endurance mission to evaluate the UUV's navigational accuracy. Secondary objectives include obtaining the UUV radiated noise signature and demonstrating performance of UUV onboard sensors, including the side-scan sonar and the Acoustic Doppler Current Profiler. A passive acoustic sensor is used to obtain a radiated-noise signature of the UUV.

The tracking sonar is active prior to and after the test run to locate the sensor accurately for post-test run analysis. A hydrophone is used to measure surrounding (ambient) noise prior to the test runs and after the test runs for comparison to vehicle-radiated noise that is acquired during the run. During this example scenario, active sonars (side-scan sonar, acoustic Doppler current profiler, and tracking sonars) emit at source levels of 203-235 dB re 1 μPa @ 1 m and at frequencies of 10 to 700 kHz. The total estimated operational test time is approximately 80 hours, including UUV launch and retrieval.

The combination of the following characteristics provide a unique testing environment at the DBRC Range Site. These characteristics include moderately deep water, permanent bottom-mounted instrumentation for Fleet submarine safety and navigation, shore-to-shore surveillance, and capability for barge access (retrieval/moorage). The bottom of the DBRC is unique compared to the other two range sites in that it has steep side walls with depths up to 600 ft (183 m).

1.3.3 Current QUTR Range Site Activities

Activities currently conducted at the QUTR Site are listed in Table 2-1; Figure 1-7 illustrates an example scenario for current activities within the QUTR Site. The primary objective of this example scenario is to evaluate and test shallow water acoustic technology in a reverberant environment, with a diesel-electric submarine simulating a potential threat target. The example scenario consists of ranging a test vehicle with a diesel-electric submarine operating at periscope depth. The test vehicle is launched from the launch craft.

To support this example scenario, the existing QUTR Site underwater-tracking equipment requires recalibration for high accuracy tracking capability. To supplement the underwater-tracking equipment the portable tracking range assets would be deployed. An additional range craft deploys the Over-the-Side/Stationary Target (schematic representation in Figure 1-6a). The submarine enters the range area at the commencement of the range exercise. The exercise torpedo is launched and makes its attack on the submarine and the over-the-side stationary target. Vehicle retrieval is accomplished through use of a retrieval craft. The estimated test time is 10 hours for the exercise and 2 to 10 days for range gear set up and removal.

In addition to tracking provided at the range, the range craft are equipped with global positioning system (GPS) tracking. The range craft transit to the range site for range activities. The test vehicle and associated support hardware are prepared in a NUWC Keyport shop and transported to KB Docks at SUBASE Bangor via truck for load-out onto the launch craft. During this test, mid- and high-frequency acoustic sources are at levels up to 226 dB re 1 μPa @ 1 m and at frequencies between 12 and 45 kHz. Upon completion of the test, all craft return to KB Docks for equipment offload. Current shore operations include maintenance and surveillance of: 1) cabling from Kalaloch; and 2) bottom-mounted instrumentation.

The combination of the following characteristics provide a unique testing environment at the QUTR Site. These characteristics include the proximity to Navy Fleet assets such as air operations, a large operational area for maneuvering multiple Fleet Assets, and an open ocean environment. The bottom within the permanently mounted tracking range is hard sand bottom with mild slope and relatively shallow water (150-300 ft [46 – 91 m]). This area is not suitable for permanent bottom-mounted equipment due to the dynamic nature of the sand bottom. The hard sand bottom and shallow depths provides a very reverberant acoustic setting where multiple bounces can be used to test torpedo detection, classification and localization capability.

1.3.4 Action Alternatives

As the three range sites within the NAVSEA NUWC Keyport Range Complex are geographically distinct, the set of alternatives for one range site is independent of the set of alternatives for another range site.

Therefore, action alternatives are presented for each range site separately. For each range site, one or more action alternatives have been identified in addition to the No-Action Alternative and are summarized below and in Table 1-4.

- Keyport Range Site: Keyport Range Alternative 1 (Preferred Alternative) – extend range boundaries to the north, east and south, increasing the size of the range from 1.5 nm^2 to 1.7 nm^2 (5.1 km^2 to 5.9 km^2) (Figure 1-2). The average annual days of use of the Keyport Range Site under this alternative would increase from the current 55 days to 60 days (Table 2-1).
- DBRC Site: DBRC Alternative 1 – extend the southern boundary of this range approximately 11.3 nm (38.7 km). DBRC Alternative 2 (Preferred Alternative) – extend the southern boundary to the Hamma Hamma River plus extend the northern boundary to 1 nm (2 km) south of the Hood Canal Bridge (Highway 104) (Figure 1-2). The preferred alternative would increase the size of the current operating area (in the case of the Preferred Alternative from approximately 32.7 nm^2 [112.1 km^2] to approximately 45.7 nm^2 [150.8 km^2]) and would afford a straight run of approximately 27.5 nm (50.9 km). The same numbers and types of activities would occur under each DBRC Site alternative and there would be no increase in average annual days of use (Table 2-1).
- QUTR Site: QUTR Alternative 1 – extend the range boundaries to coincide with the overlying special use airspace of W-237A plus locate a 8.4 nm^2 (28.8 km^2) surf zone at Kalaloch. The total range area under QUTR Alternative 1 would increase from approximately 48.3 nm^2 (165.5 km^2) to approximately 1,840.4 nm^2 (6,312.4 km^2). QUTR Alternative 2 (Preferred Alternative) – extend the range boundaries the same as Alternative 1 but locate a 7.8 nm^2 (26.6 km^2) surf zone at Pacific Beach instead of at Kalaloch. The total range area under QUTR Alternative 2 would be 1,839.8 nm^2 (6,310.2 km^2). QUTR Alternative 3 – extend the range boundaries the same as Alternative 1 but locate a 22.6 nm^2 (77.6 km^2) surf zone at Ocean City instead of at Kalaloch. The total range area under QUTR Alternative 3 would be 1,854.6 nm^2 (6,361.2 km^2). The average annual number of days of use for offshore activities would increase under each QUTR Site action alternative from 14 days/year to 16 days/year in the offshore area. The average annual days of use for surf-zone activities would increase from 0 days/year to 30 days/year (Table 2-1).

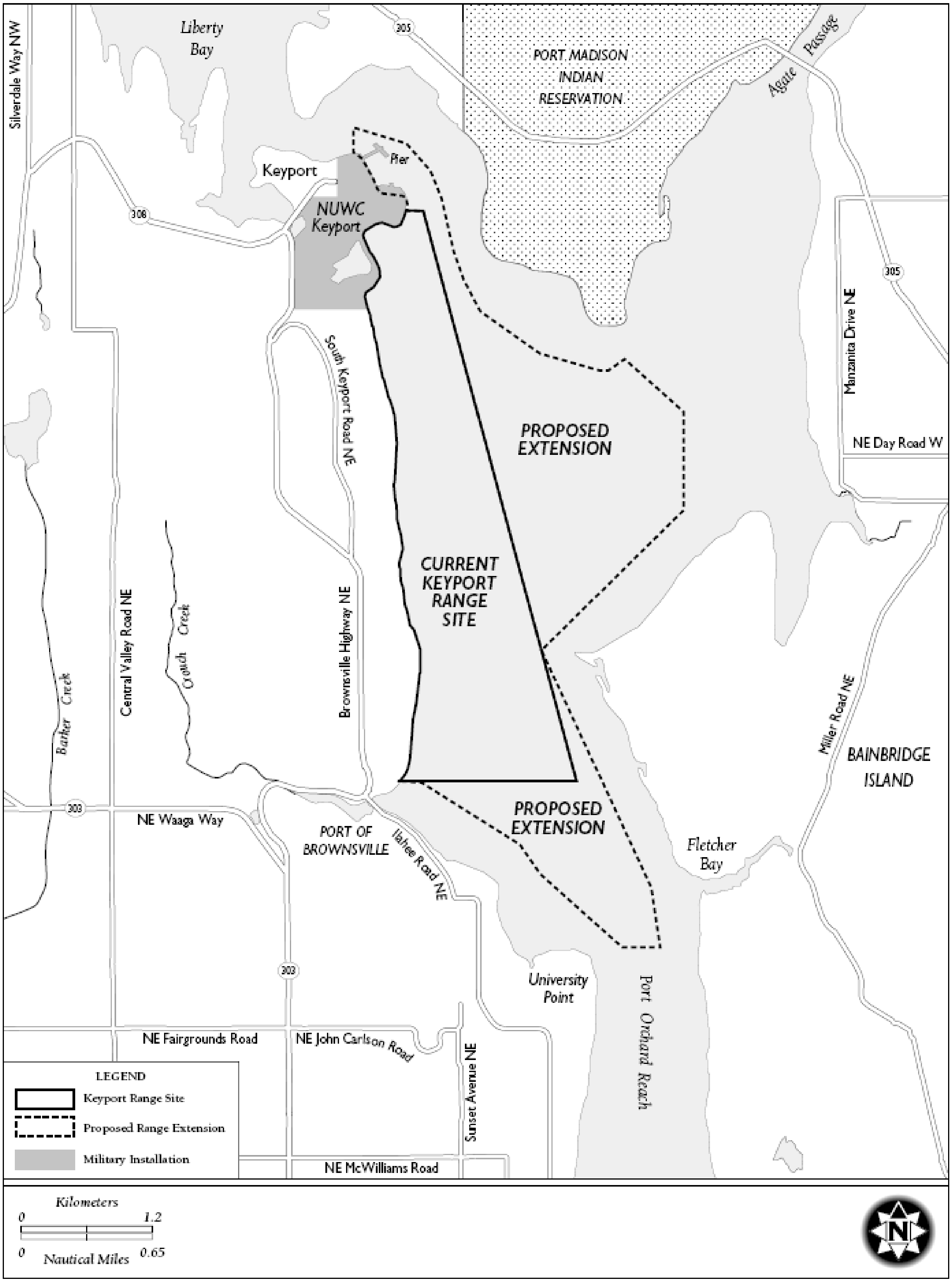

Figure 1-2: Keyport Range Alternative 1, Proposed Extension

Table 1-4: Proposed Annual Range Activities and Operations

Range Activity	*Platform/System Used*	*Proposed Annual Operations*		
		Keyport Site	*DBRC Site*	*QUTR Site*
Test Vehicles Propulsion	Thermal propulsion systems	5	130	30
	Electric/Chemical propulsion systems	55	140	30
Other Testing Systems and Activities	Submarine testing	0	45	15
	Inert Mine detection, classification and localization	5	20	10
	Non-Navy testing**	5	5	5
	Acoustic & non-acoustic sensors (e.g., magnetic array and oxygen)	20	10	5
	Countermeasure test	5	50	5
	Impact testing	0	10	5
	Static in Water testing	10	10	6
	Unmanned Undersea Vehicle (UUV) testing	45	120	40
Fleet Operations (excluding Launches)	Surface Ship activities	1	10	10
	Aircraft activities	0	10	10
	Submarine activities	0	30	30

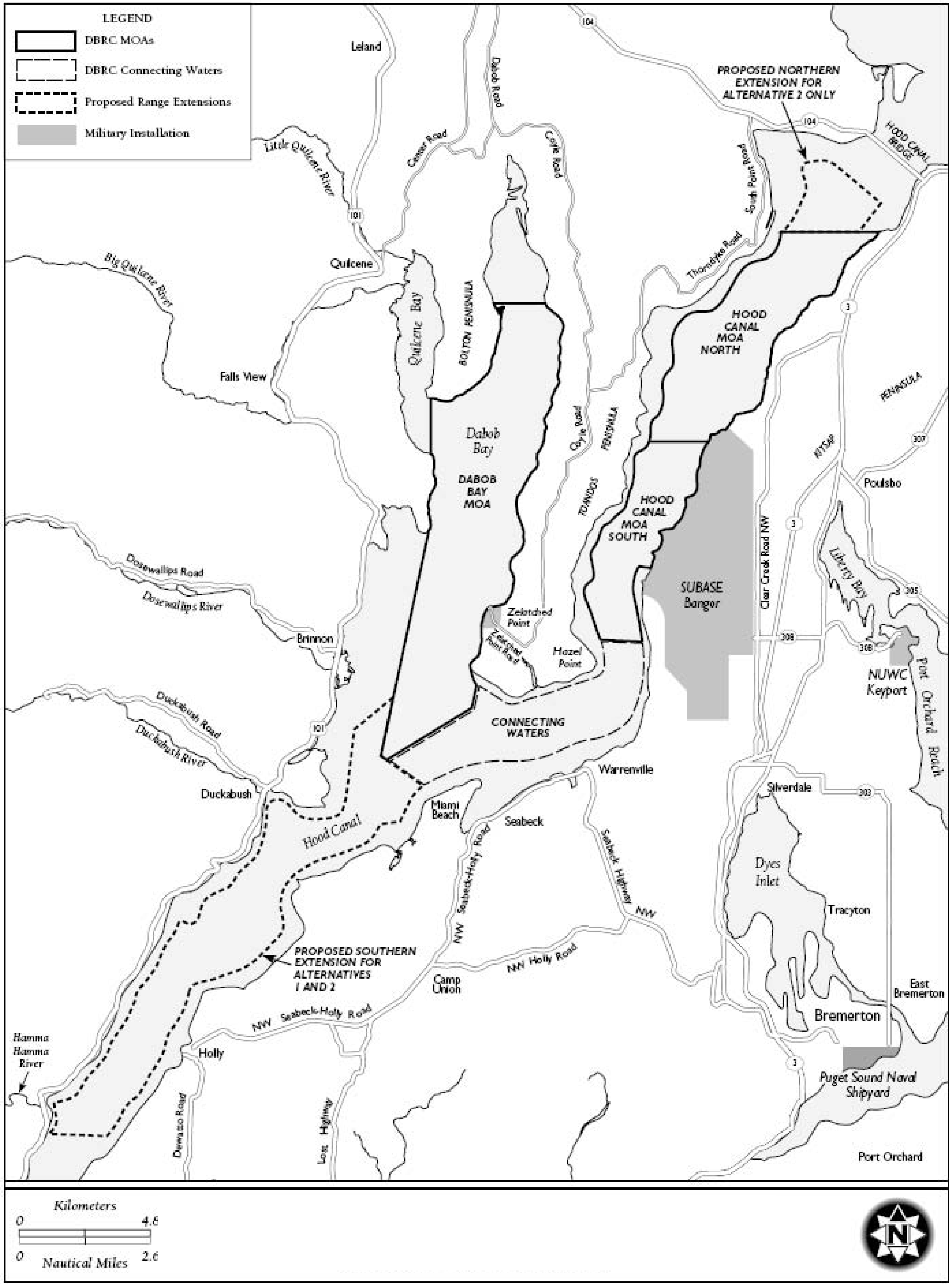

Figure 1-3: Proposed DBRC Site Extensions: Alternative 1 and Alternative 2

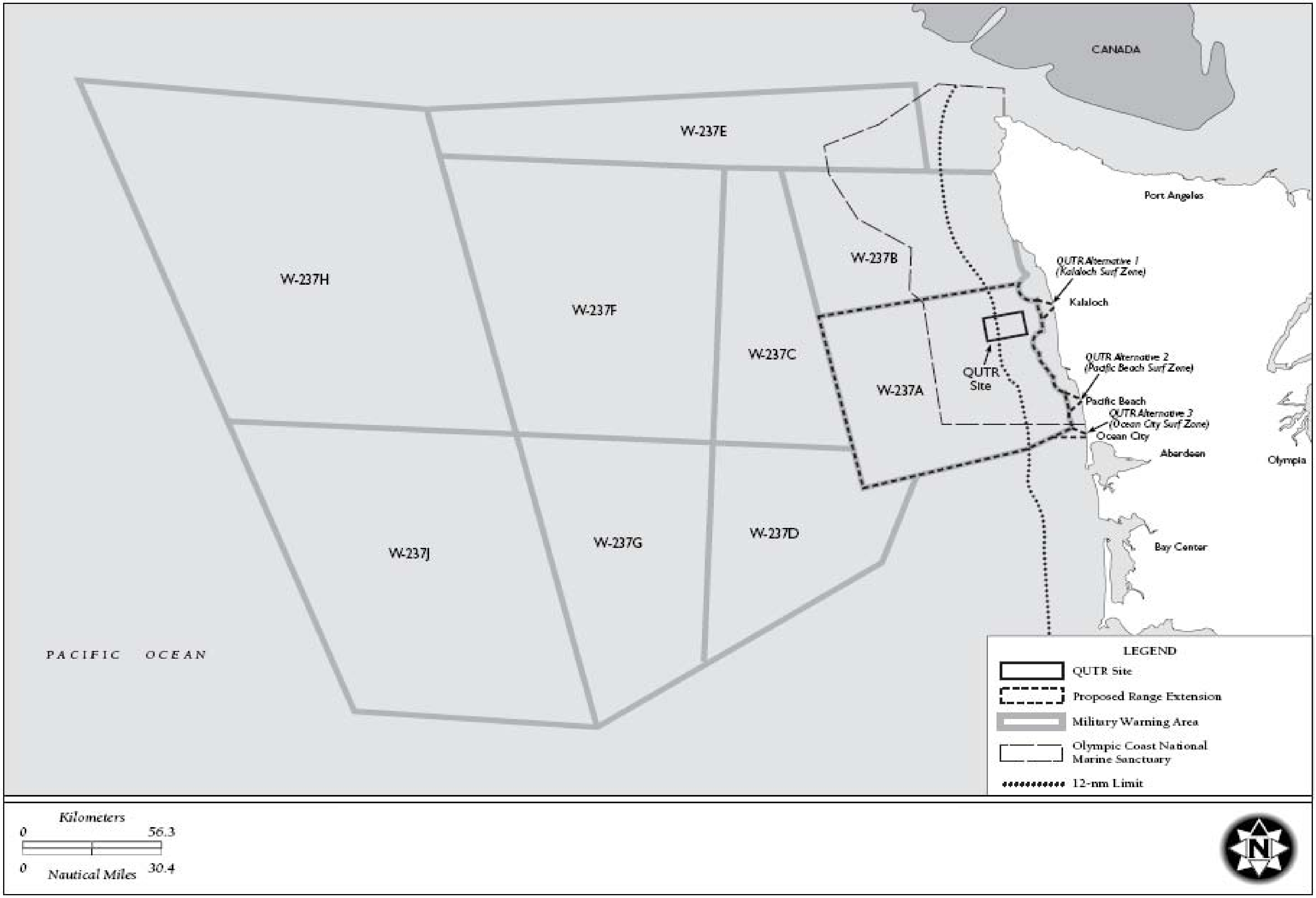

Figure 1-4: Proposed QUTR Site Extension Common to all Alternatives

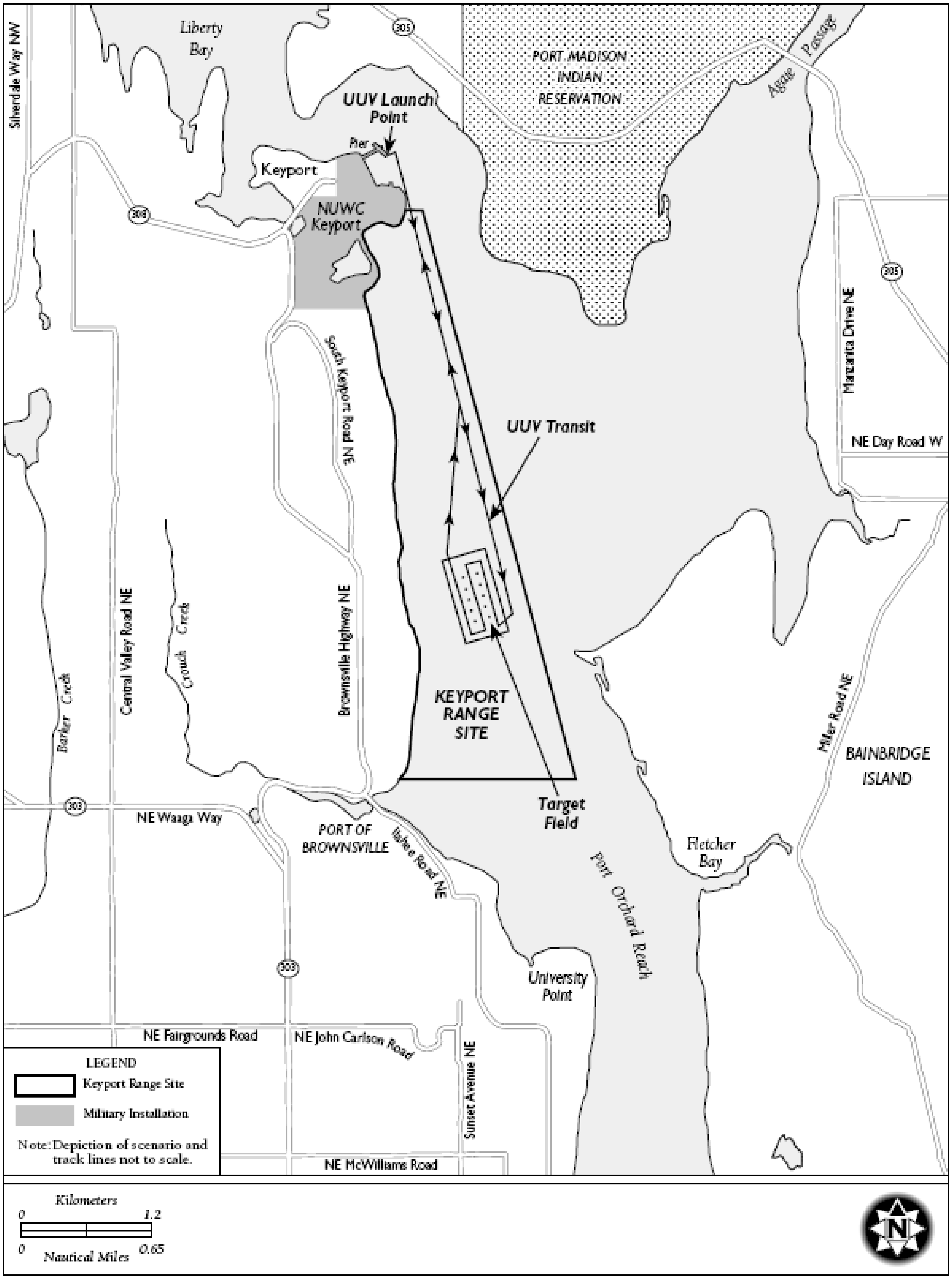

Figure 1-5: Keyport Range Site, Example Operational Scenario

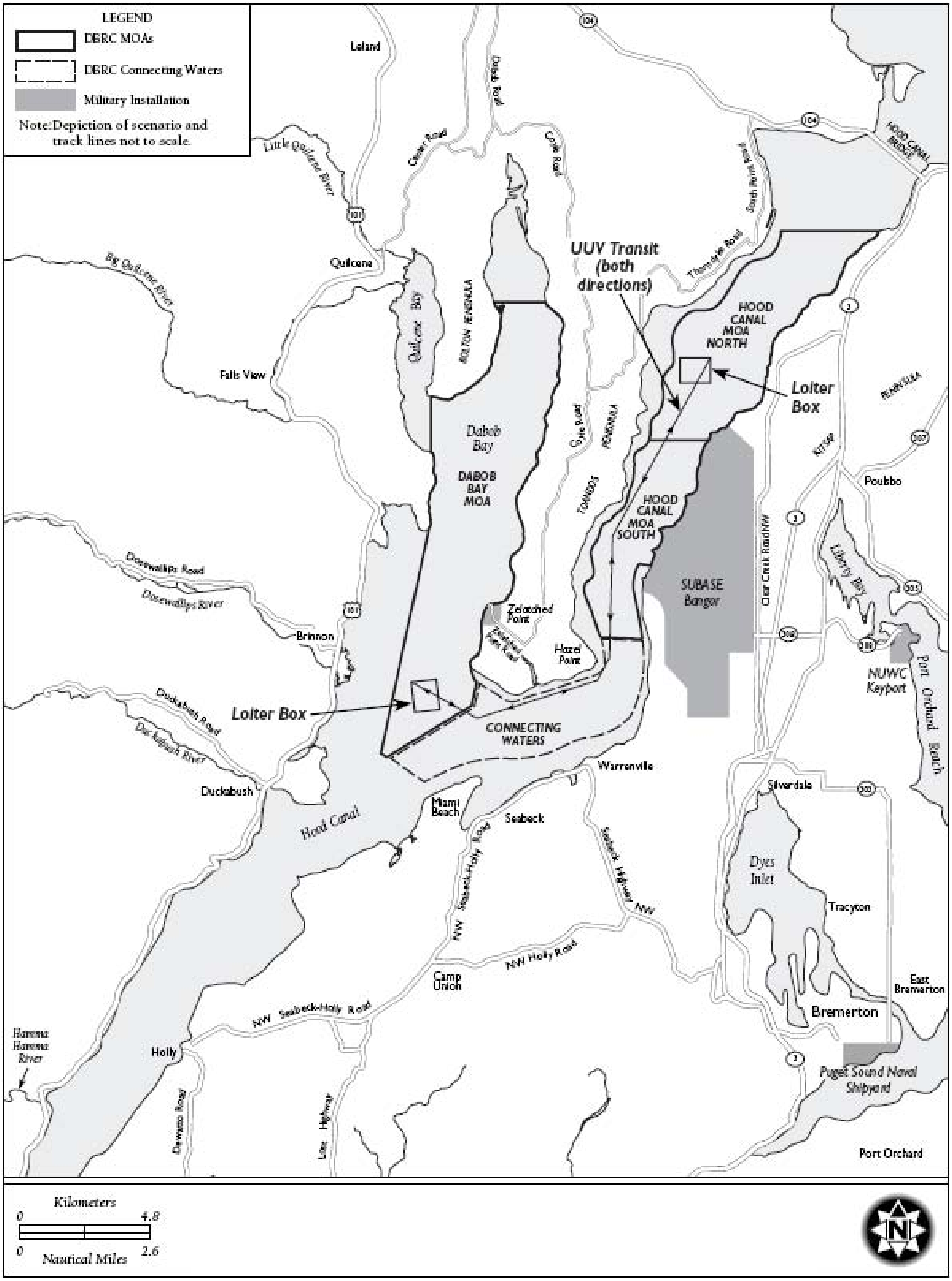

Figure 1-6: DBRC Site, Example Operational Scenario

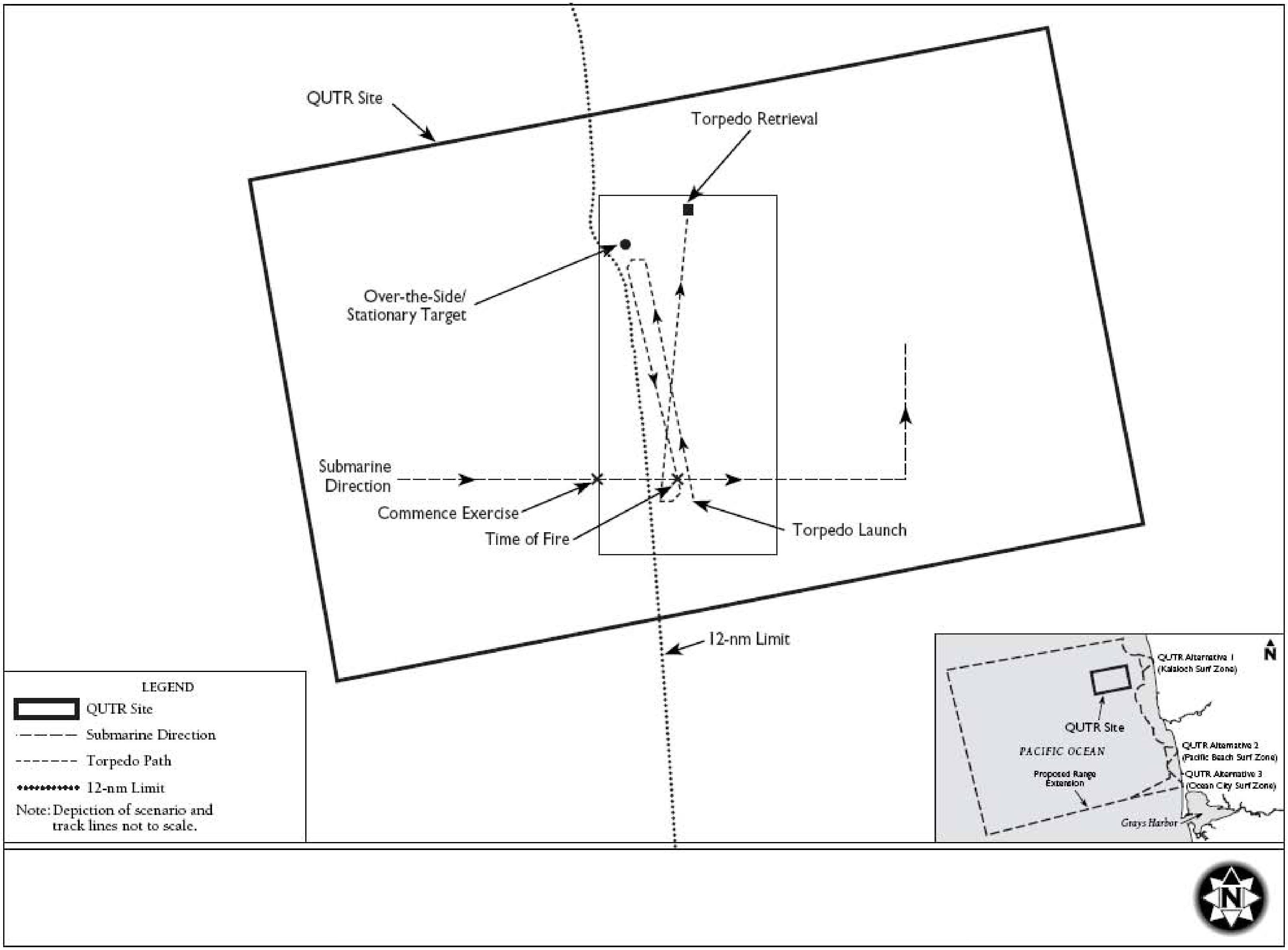

Figure 1-7: QUTR Site, Example Operational Scenario

2 DURATION AND LOCATION OF ACTIVITIES

The NAVSEA NUWC Keyport Range Complex Extension consists of three range sites; the Keyport Range Site, Dabob Bay Range Complex (DBRC), and the Quinault Underwater Tracking Range (QUTR) Site. Together, the NAVSEA NUWC Keyport Range Complex Extension consists of geographically diverse locations.

The NAVSEA NUWC Keyport Range Complex Extension is divided into open ocean/offshore areas and in shore areas:

- Open Ocean Area – air, surface, and subsurface areas of the NAVSEA NUWC Keyport Range Complex Extension that lie outside of 12 nautical miles (nm) from land.
- Offshore Area – air, surface, and subsurface ocean areas within 12 nm of the Pacific Coast.
- In shore – air, surface, and subsurface areas within the Puget Sound, Port Orchard Reach, Hood Canal, and Dabob Bay.

All range areas in the NAVSEA NUWC Keyport Range Complex Extension include areas where marine mammals may be found. Figure 1-1 illustrates the sites within the Range Complex Extension. Range activities will be conducted in the Keyport Site, the DBRC, and the QUTR Site. The proposed annual usage at each site is listed in Table 2-1. This includes tracking sonar systems, side-scan, and thermal propulsion systems. The QUTR Site will increase all submarine, inert mine, static in water, and UUV activities.

Table 2-1: Projected Annual Days of Use by Range Site

	Keyport Range Site	*DBRC Site*	*QUTR Site – Offshore*	*QUTR Site– Surf Zone*
Current	55	200	14	0
Proposed	60	200	16	30

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3 MARINE MAMMAL SPECIES AND NUMBERS

The information contained in this Chapter relies on the data gathered in the Marine Resources Assessment (MRA) for the Pacific Northwest Operating Area, which includes the NAVSEA NUWC Keyport Range Complex. In addition, literature searches were conducted using the search engines: Biosis, Cambridge Abstract's Aquatic Sciences, University of California Melvyl, and Zoological Record Plus. Searches were also conducted on peer review 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, and Aquatic Mammals). References were also obtained from previous environmental documents from applicants or resource agencies, and mitigation or monitoring reports etc.

A total of 19 cetacean species, 5 pinniped species, and the sea otter (mustelid) are known to occur in Washington waters; however, several are seen only rarely. All marine mammals are protected under the MMPA and some are also listed as threatened or endangered under the ESA (Table 3-1, 3-2, and 3-3).

3.1 Marine Mammal Occurrence

The MRA data, supplemented with other resources and more recent references, were used to provide a regional context for each species. The data were compiled from available sighting records, literature, satellite tracking, and stranding and by-catch data. The most abundant marine mammals are *mysticetes* (baleen whales or the large whales with baleen) and *odontocetes* (toothed whales or porpoises and dolphins), which are known collectively as cetaceans; *pinnipeds* (seals and sea lions); and *mustelids* (sea otter). The pinnipeds are further divided into eared seals or otariids such as sea lions and fur seals, and earless seals or phocids such as harbor seals and elephant seals.

Seven marine mammal species listed as Federally-endangered under the Endangered Species Act (ESA) occur or have the potential to occur in the area: blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), Sei whale (*Balaenopterus borealis*), humpback whale (*Megaptera novaengliae*), north Pacific right whale (*Eubalaena japonica*), sperm whale (*Physeter catodon*), and the southern resident population of killer whales (*Orcinus orca*). The threatened species is the Steller's sea lion (*Eumetopias jubatus*).

A separate consultation is underway with NMFS to evaluate potential effects to these species under the ESA.

3.2 Estimated Marine Mammal Densities

Survey data in the inland waters of Puget Sound is sparse. There have been few comprehensive studies of marine mammals in inland waters, and those that have occurred have focused on inland waters farther north (Strait of Juan de Fuca, San Juan/Gulf Islands, Strait of Georgia; Osmek et al. 1998). Most published information focuses on single species (e.g., harbor seals, Jeffries et al. 2003) or are stock assessment reports published annually by the National Marine Fisheries Service (NMFS) (e.g., Carretta et al. 2007).

Survey data for the offshore waters of Washington State, including the area of the QUTR Site, are somewhat better particularly for cetaceans. The NMFS conducted vessel surveys in the region in 1996 and 2001, which are summarized in Barlow (2003) and Appler et al. (2004). Vessel surveys were again conducted by NMFS in summer 2005, and included finer-scale survey lines within the OCNMS (Forney 2007). Cetacean densities from this most recent effort were used wherever possible; older density values (2001 or 1996) were used when more recent values were not available. Species with rare or extralimital occurrence off Washington State are included in the species summaries in Section 4; however, there are no densities available and they are not included in Tables 3-1, 3-2, 3-3. Some cetacean densities (gray and killer whale, harbor porpoise) were obtained from sources other than the broad scale surveys indicated above and the methodologies of deriving the densities are included here in some detail.

Pinniped at-sea density is not often available because pinniped abundance is most often obtained via shore counts of animals at known rookeries and haulouts. Therefore, densities of pinnipeds were derived differently from those of cetaceans. Several parameters were identified from the literature, including area of stock occurrence, number of animals (which may vary seasonally) and season, and those parameters were then used to calculate density. Determining density in this manner is risky as the parameters used usually contain error (e.g., geographic range is not exactly known and needs to be estimated, abundance estimates usually have large variances) and, as is true of all density estimates, it assumes that animals are always distributed evenly within an area which is likely rarely true. However, this remains one of the few means available to determine at-sea density for pinnipeds.

Sea otters occur along the northern Washington coast. Density of sea otters was published as animals/km, which was modified to provide density per area.

Tables 3-1, 3-2, and 3-3 list the temporal distribution and abundance of marine mammals throughout the NAVSEA NUWC Keyport Range Complex Extension.

3.2.1 Keyport Range Site

A total of five cetaceans and three pinnipeds are known to occur within central Puget Sound, which encompasses the Keyport action area, but several of these species have never been observed in Port Orchard Narrows or in the action area (Table 3-1). Humpback whales, minke whales, killer whales, and Steller's sea lions are expected to be uncommon to rare in southern Puget Sound and have never been seen in the Keyport action area. Density estimates for these species are available for Puget Sound as a whole, but since these species have never been recorded or observed in the action area, the densities for the action area are shown as “0” to reflect this.

Table 3-1: Marine Mammals Known to Occur or Potentially Occur within the Keyport Action Area

				Density Estimate (km^2)	
Species		*Status ESA/MMPA*	*Occurrence in Keyport Action Area*	*Warm Season*	*Cold Season*
CETACEANS					
Mysticetes					
Minke whale		-/-	Very rare, year round.	0(a)	0(a)
Humpback whale		E/D	Very rare, warm season; has never been recorded in action area.	0(a)	0(a)
Gray whale		-/-	Very rare, migrant and summer/fall resident population in primarily northern Puget Sound.	0(a)	0(a)
Odontocetes					
Killer whale	Transient	-/-	Very rare, year round; has never been recorded in action area.	0(a)	0(a)
	S Resident	E, CH/D	Very rare, summer/fall season; has never been recorded in action area.		
Dall's porpoise		-/-	Rare, year round.	0(a)	0(a)
PINNIPEDS					
Harbor seal		-/-	Common year-round resident.	0.55	0.55
California sea lion		-/-	Rare, cold season.	0(a)	0(a)
Steller's sea lion		T/D	Rare, cold season; has never been recorded in action area.	0(a)	0(a)

Notes: D = Depleted, E = Endangered, CH = Critical Habitat, T = Threatened.

Warm season = May-October, Cold season = November-April.

abundant = the species is expected to be encountered during a single visit to the area and the number of individuals encountered during an average visit may be as many as hundreds or more; **common** = the species is expected to be encountered once or more during 2-3 visits to the area and the number of individuals encountered during an average visit is unlikely to be more than a few 10s; **uncommon** = the species is expected to be encountered at most a few times a year; **rare** = the species is not expected to be encountered more than once in several years; **very rare** = not expected to be encountered more than once in 10 years.

(a) Density estimates for these species were calculated for Puget Sound as a whole, but these species have never been recorded or observed in the action area. Thus the densities for the action area are shown as "0" to reflect this.

3.2.2 DBRC Site

Five cetaceans and three pinnipeds are known to occur or potentially occur within the DBRC action area (Table 3-2). The general ecology and natural history for each of these species is presented in Section 4, *Affected Species Status and Distribution*. ESA-listed species are discussed separately at the beginning of this section; there is no designated or proposed critical habitat for marine mammals within the DBRC action area.

Table 3-2: Marine Mammals Known to Occur or Potentially Occurring within the DBRC Action Area

Species		*Status* *ESA/MMPA*	*Occurrence in DBRC Action Area*	*Density Estimate (km^2)* *Warm Season*	*Cold Season*
CETACEANS					
Mysticetes					
Minke whale		-/-	Very rare, year round; has never been recorded in action area.	0(a)	0(a)
Humpback whale		E/D	Very rare, warm season migrant; has never been recorded in action area.	0(a)	0(a)
Gray whale		-/-	Very rare, spring/fall migrant and summer/fall resident population in primarily northern Puget Sound.	0(a)	0(a)
Odontocetes					
Killer Whale	Transient	-/-	Uncommon, spring/summer.	Jan-Jun: 0.038	Jul-Dec: 0
	S Resident	E, CH/D	Very rare; no recorded occurrences in Hood Canal.	0(a)	0(a)
Dall's porpoise		-/-	Very rare, year round.	0	0
PINNIPEDS					
Harbor seal		-/-	Common year-round resident.	1.31	1.31
California sea lion		-/-	Common resident and seasonal migrant.	0	0.052
Steller's sea lion		T/D	Very rare, cold season; has never been recorded in action area.	0(a)	0(a)

Notes: D = Depleted, E = Endangered, CH = Critical Habitat, T = Threatened.

Warm season = May-October, Cold season = November-April; *

abundant = the species is expected to be encountered during a single visit to the area and the number of individuals encountered during an average visit may be as many as hundreds or more; **common** = the species is expected to be encountered once or more during 2-3 visits to the area and the number of individuals encountered during an average visit is unlikely to be more than a few 10s; **uncommon** = the species is expected to be encountered at most a few times a year; **rare** = the species is not expected to be encountered more than once in several years; **very rare** = not expected to be encountered more than once in 10 years.

(a)These species have never been recorded or observed in the action area. Thus the densities for the action area are shown as "0" to reflect this.

3.2.3 QUTR Site

The diversity of marine mammals that occur in QUTR is greater than that in the Puget Sound ranges (Table 3-3). They include species present all year, species that occur seasonally, and those that merely migrate through the area.

Table 3-3: Marine Mammals Known to Occur or Potentially Occurring within the QUTR Action Area

Species		*Status* ESA/MMPA*	*Occurrence in QUTR Action Area*	*Density Estimate (km^2)*	
				Warm Season	*Cold Season*
CETACEANS					
Mysticetes					
Blue whale		E/D	Rare, warm season.	0.0003	0
Fin whale		E/D	Rare, year-round.	0.0012	0.0012
Gray whale	Resident	-/-	Uncommon, year-round	0.003	0.003
	Migratory	-/-	Abundant briefly during cold season migrations.	0	See text
Humpback whale		E/D	Uncommon, warm season.	0.0237	0
Minke whale		-/-	Rare, year-round.	0.0004	0.0004
North Pacific right whale		E/D	Very rare, warm season.	0[a]	0[a]
Sei whale		E/D	Very rare, year-round.	0.0002	0.0002
Odontocetes					
Baird's beaked whale		-/-	Uncommon, year-round.	0.0027	0.0027
Hubb's and Stejneger's beaked whale		-/-	Uncommon, year-round	0.0027	0.0027
Dall's porpoise		-/-	Abundant, year-round	0.1718	0.1718
Harbor porpoise		-/-	Abundant, year-round	2.86	2.86
Northern right whale dolphin		-/-	Common, year-round	0.0419	0.0419
Pacific white-sided dolphin		-/-	Abundant, warm season	0.1929	0
Risso's dolphin		-/-	Uncommon, year-round	0.002	0.002
Short-beaked common dolphin		-/-	Uncommon, warm season.	0.0012	0
Striped dolphin		-/-	Very rare, warm season.	0.0002	0
Dwarf & pygmy sperm whales		-/-	Uncommon, warm season.	0.0015	0
Sperm whale		E/D	Uncommon, year-round	0.0011	0.0011
Killer whale (densities for all populations)	N Resident	-/-	Rare, year-round.	0.0028	0.0028
	S Resident	E/D	Rare, year-round.		
	Offshore	-/-	Uncommon, year-round.		
	Transient	-/-	Uncommon, cold season.		
PINNIPEDS					
Phocids					
Harbor seal		-/-	Abundant, year-round.	0.44	0.44
Northern elephant seal		-/-	Uncommon, year-round.	Dec-Feb: 0.019 Mar-Apr: 0.026 May-Jul: 0.038 Aug-Nov: 0.047	
Otariids					
California sea lion		-/-	Common, year-round except May-July	Aug-Apr: 0.283 May-Jul: 0	
Northern fur seal		-/D	Common, year-round.	0.091	0.117
Steller sea lion		T/D	Uncommon, year-round.	0.0096	0.0096
MUSTELIDS					
Sea otter		-/-	Does not presently occur within the action area.	0[a]	0[a]

Notes: Warm season = May-October, Cold season = November-April. *D = depleted, E = endangered, T = threatened.

abundant = expected to be encountered during a single visit to the area and the number of individuals encountered during an average visit may be as many as hundreds or more; **common** = expected to be encountered once or more during 2-3 visits to the area and the number of individuals encountered during an average visit is unlikely to be more than a few 10s; **uncommon** = expected to be encountered at most a few times a year; **rare** = not expected to be encountered more than once in several years; **very rare** = not expected to be encountered more than once in 10 years.

(a)These species have not typically been recorded or observed in the action area. The densities for the action area are shown as "0" to reflect this.

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4 AFFECTED SPECIES STATUS AND DISTRIBUTION

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 NAVSEA NUWC Keyport Range Complex. 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 Threatened and Endangered Marine Mammals of the NAVSEA Keyport Range Complex Extension

There are eight marine mammal species that are listed as endangered or threatened under the Endangered Species Act (ESA) with confirmed or possible occurrence in the study area. The endangered species include the blue whale, fin whale, humpback whale, north Pacific right whale, sei whale, sperm whale and the southern resident killer whale. The threatened species is the Steller's sea lion. Within the NAVSEA NUWC Keyport Range Complex and proposed extension areas, rarely are the threatened or endangered species ever found.

Each marine mammal species is described below with available stock, status, distribution with likely occurrence in the study area, diving behavior and acoustic information.

4.1.1 Blue Whale (*Balaenoptera musculus*)

Stock. Eastern North Pacific

Status. The blue whale is listed as endangered under the ESA and as a depleted and strategic stock under the Marine Mammal Protection Act (MMPA). The blue whale was severely depleted by commercial whaling in the twentieth century (NMFS, 1998). There is no designated critical habitat for this species in the North Pacific.

Abundance. The best estimate of the blue whale in the area of California, Oregon and Washington states is 1,744 (CV = 0.28; Carretta et al. 2007). There is no information on the population trend of blue whales.

Distribution. Blue whales are distributed from the ice edges to the tropics in both hemispheres (Jefferson et al., 1993). Blue whales migrate to high latitudes in the summer and move into the subtropics and tropics during the winter for calving season (Yochem and Leatherwood, 1985). Data from both the Pacific and Indian Oceans, however, indicate that some individuals may remain in low latitudes year-round, such as over the Costa Rican Dome (Reilly and Thayer, 1990). The productivity of the Costa Rican Dome may allow blue whales to feed during their winter calving/breeding season and not fast, like humpback whales (Mate et al., 1999).

Blue whales usually are found singly or in small groups (average 2.5 individuals). Although most blue whales feed in waters off California from May through November and migrate to waters off Mexico where they spend winter and spring, some range as far north as British Columbia (Calambokidis and Barlow 2004). However, recent passive acoustic monitoring indicated that the greatest blue whale call activity in the northeast Pacific occurred during the winter months, suggesting that not all blue whales migrate south during the fall and winter. During extensive vessel-based surveys along the Washington coast in 1996 and 2001, zero and three sightings were recorded, respectively. Blue whale numbers seem to be increasing in abundance in Californian waters (Calambokidis and Barlow 2004), and an estimated 101 blue whales occur along the outer Washington and Oregon coasts (Barlow 2003).

Blue whales are rare within the Puget Sound area (DoN, 2006). Density of blue whales was estimated at $0.0003/km^2$, based on surveys conducted in 2001 off Oregon and Washington (Barlow 2003). This estimate is applicable to the Quinalt range from May to October. The density for the Dabob Bay and Keyport ranges is zero, as blue whales are no known to inhabit inland Washington waters (Appendix A).

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. and for 7.8 minutes (min) when foraging and to 222 ft. and for 4.9 min when not foraging. Blue whales feed on euphasiid crustaceans, including *Euphasia* sp. And *Thysanoessa* so. (Sears 2002). They have been documented feeding near the surface as well as at depths exceeding 140m (Croll et al. 2001). Data from southern California and Mexico showed that whales dived to >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 ~ 30m. 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 ~ 30m. 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):78% in 0-16 m, 9% in 17-32 m, 13% in >32 m.

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

Acoustics. Blue and fin whales 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). Their frequency range 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).

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) whales while deeper diving whales (> 165 ft) were likely feeding and calling less. While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

4.1.2 Fin Whale (*Balaenoptera physalus*)

Stock. California/Oregon/Washington

Status. The fin whale is listed as endangered under the ESA and as a depleted and strategic stock under the MMPA. There is no designated critical habitat for this species in the North Pacific. The IWC recognizes two management stocks in the North Pacific: a single widespread stock in the North Pacific and a smaller stock in the East China Sea (Donovan, 1991). The NOAA stock assessment report recognizes three stocks of fin whales in the North Pacific: (1) the Hawaii stock; (2) the California/Oregon/Washington stock; and (3) the Alaska stock (Carretta et al., 2005). There is no information on the population trend of fin whales.

The fin whale population in the entire North Pacific is well below pre-whaling numbers, although there is some indication that it may be growing. Although typically associated with offshore waters, whalers frequently encountered this species in some of the channels and inlets on the northern coast of British Columbia and sightings have been recorded in the past decade in British Columbia waters (Gregr and Trites 2001). An analysis of whaling records confirmed anecdotal evidence that fin whales once spent extended periods in the coastal waters (Gregr et al. 2000). Fin whales feed on euphausids, copepods, squid, and small schooling fish (Flinn et al. 2002).

Passive acoustic monitoring of fin whale vocalizations are detected year-round off Oregon and Washington with a concentration of vocal activity between September and February, suggesting that this area may be a winter feeding area (Moore et al. 1998). Animals that winter off California range from California to the Gulf of Alaska during the summer months (Rice 1974). The estimated population size of the Oregon/Washington stock of fin whales based on ship surveys in 1996 and 2001 was 283-380 individuals (Barlow 2003).

Abundance and Distribution. The initial pre-whaling population of fin whales in the North Pacific was estimated to be 42,000-45,000 (Ohsumi and Wada 1974). In 1973, the North Pacific population was estimated to have been reduced to 13,620-18,680 (Ohsumi and Wada 1974), of which 8,520-10,970 were estimated to belong to the eastern Pacific stock. A minimum of 148 individually-identified fin whales were found in the Gulf of California (Tershy et al. 1990). Recently 3,279 (CV = 0.31) fin whales were estimated to be off California, Oregon and Washington based on ship surveys in summer/autumn of 1996 (Barlow and Taylor 2001) and 2001 (Barlow 2003). This is probably a slight underestimate because it almost certainly excludes some fin whales which could not be identified in the field and which were recorded as “unidentified rorqual” or “unidentified large whale”. Based on this survey data, the density estimate is 0.0012/km^2 for the QUTR Action Area year round. As fin whales are not known to inhabit the inland waters of Washington, the density of fin whales for both Dabob Bay and Keyport ranges are zero (Appendix A).

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 (Standard Deviation [SD] = ± 106.8 ft) with a duration of 6.3 min (SD = ± 1.53 min) when foraging and to 168 ft (SD = ± 97.3 ft) 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 and dive durations of 6.2-7.0 min. Fin whale dives exceeding 492 ft 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 (<100m) and night dives were deeper (>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 (<50m); dives were to >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 40% at <50m, 20% at 50-225 m (covering the ascent and descent times) and 20% at >225 m.

Acoustics. Fin and blue whales produce calls with the lowest frequency and highest source levels of all cetaceans. Infrasonic, pattern sounds have been documented for fin whales (Watkins et al., 1987; Clark and Fristrup, 1997; McDonald and Fox, 1999). Fin whales 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 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) recently 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 (Watkins et al., 1987). While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

4.1.3 Humpback Whale (*Megaptera novaengliae*)

Stock. Eastern North Pacific

Status. The humpback whale is listed as endangered under the ESA and as a depleted and strategic stock under the MMPA (Carretta et al., 2005). There is no designated critical habitat for this species in the North Pacific. Evidence suggests that some humpback whales may move between the waters of Japan in the Western North Pacific (Darling and Cerchio, 1993; Salden, et al., 1999; Calambokidis et al., 2001; Witteveen et al., 2004).

Abundance and Distribution. Although the IWC only considered one stock (Donovan 1991), there is now good evidence for multiple populations of humpback whales in the North Pacific (Johnson and Wolman 1984; Baker et al. 1990). Aerial, vessel, and photo-identification surveys, and genetic analyses indicate that within the U.S. EEZ, there are at least three relatively separate populations that migrate between their respective summer/fall feeding areas and winter/spring calving and mating areas (Calambokidis et al. 2001, Baker et al. 1998): 1) winter/spring populations in coastal Central America and Mexico which migrate to the coast of California to southern British Columbia in summer/fall (Steiger et al. 1991, Calambokidis et al. 1996) - referred to as the eastern North Pacific stock; 2) winter/spring populations of the Hawaiian Islands which migrate to northern British Columbia/Southeast Alaska and Prince William Sound west to Kodiak (Baker et al. 1990, Perry et al. 1990, Calambokidis et al. 2001) - referred to as the central North Pacific stock; and 3) winter/spring populations of Japan which, based on Discovery Tag information, probably migrate to waters west of the Kodiak Archipelago (the Bering Sea and Aleutian Islands) in summer/fall (Berzin and Rovnin 1966, Nishiwaki 1966, Darling 1991) - referred to as the western North Pacific stock.

Winter/spring populations of humpback whales also occur in Mexico’s offshore islands; the migratory destination of these whales is not well known (Calambokidis et al. 2001), but Norris et al. (1999) speculate that they may travel to the Bering Sea or Aleutian Islands. This stock structure represents the predominant migration patterns, but there is not a perfect correspondence between the breeding and feeding areas that are paired above. For example, some individuals migrate from Mexico to the Gulf of Alaska and others migrate from Japan to British Columbia. In general, interchange occurs (at low levels) between breeding areas, but fidelity is extremely high among the feeding areas (Calambokidis et al. 2001).

Until further information becomes available, three management units of humpback whales (as described above) are recognized within the U.S. EEZ of the North Pacific: the eastern North Pacific stock (this report), the central North Pacific stock, and the western North Pacific stock. The central and western North Pacific stocks are reported separately in the Stock Assessment Reports for the Alaska Region.

Humpback whales were sighted offshore Washington and Oregon in both 1996 and 2001 (Appler et al., 2004; Barlow, 2003), and there were several sightings during CSCAPE 2005 surveys conducted in 2005 (Forney, 2007). Density of humpbacks from surveys conducted in the OCNMS stratum in 2005 (Forney, 2007) was 0.0237/km^2 (Appendix A), which is applicable for the Quinault range for June–October. Humpback whales were once plentiful enough in the inland waters of Washington State that there were whaling stations in Victoria, British Columbia, and the Strait of Georgia. Their occurrence in inland waters is now rare, however; density for humpback whales on the Dabob Bay and Keyport ranges is zero.

<u>Diving Behavior</u>. 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 (Dietz et al., 2002), on the feeding grounds they spend the majority of their time in the upper 400 ft 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.

<u>Acoustics</u>. 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 kilohertz (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). 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. Songs have also been recorded on feeding grounds (Mattila et al., 1987; Clark and Clapham, 2004).

The main energy 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. 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 very different from the Navy's haul 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. Humpback whales also stop singing in response to playbacks of the singing or social sounds of conspecifics. Miller et al. (2000) reported that humpback whales sang longer during playbacks of low-frequency active sonar which is much lower in frequency than the mid-frequency active sonar proposed in this EIS. Recent information on the songs of humpback whales suggests that their hearing may extend to frequencies of at least 24 kHz and source levels of 151-173 dB re 1µPa (Au et al., 2006).

4.1.4 North Pacific Right Whale (*Eubalaena japonica*)

Stock. North Pacific

Status. The north Pacific right whale is listed as endangered under the ESA and as a depleted and strategic stock under the MMPA (Carretta et al., 2005). Until recently, right whales in the North Atlantic and North Pacific were classified together as a single species, referred to as the "northern right whale." Genetic data indicate that these two populations represent separate species: the North Atlantic right whale (*Eubalaena glacialis*) and the North Pacific right whale (*Eubalaena japonica*) (Rosenbaum et al., 2000) and NOAA has proposed to officially recognize *E. japonica* as a separate species (NMFS, 2006).

The North Pacific right whale is perhaps the world's most endangered large whale species (Perry et al., 1999; IWC, 2001). North Pacific right whales are classified as endangered both under the ESA and on the World Conservation Union (IUCN) Red List (Reeves et al., 2003). There are insufficient genetic or resighting data to address whether there is support for the traditional separation into eastern and western stocks (Brownell et al., 2001); however, Clapham et al. (2004) noted that north–south migratory movements support the hypothesis of two largely discrete populations of right whales in the eastern and western North Pacific. No reliable population estimate presently exists for this species; the population in the eastern North Pacific is considered to be very small, perhaps only in the tens of animals (NMFS, 2002; Clapham et al., 2004), while in the western North Pacific, the population may number at least in the low hundreds (Brownell et al., 2001; Clapham et al., 2004).

Abundance and Distribution. Right whales occur in sub-polar to temperate waters. The North Pacific right whale historically occurred across the Pacific Ocean north of 35 degrees north, with concentrations in the Gulf of Alaska, eastern Aleutian Islands, south-central Bering Sea, Sea of Okhotsk, and the Sea of Japan (Omura et al., 1969; Scarff, 1986; Clapham et al., 2004). Presently, sightings are extremely rare, occurring primarily in the Okhotsk Sea and the eastern Bering Sea (Brownell et al., 2001; Shelden et al., 2005). Prior to 1996, right whale sightings were very rare in the eastern North Pacific (Scarff, 1986; Brownell et al., 2001). Recent summer sightings of right whales in the eastern Bering Sea represent the first reliable consistent observations in this area since the 1960s (Tynan et al., 2001; LeDuc, 2001). Neither the west coast of North America nor the Hawaiian Islands constituted a major calving ground for right whales within the last 200 years (Scarff, 1986). No coastal calving grounds for right whales have been found in the western North Pacific either (Scarff, 1986). Mid-ocean whaling records of right whales in the winter suggest that right whales may have wintered and calved far offshore in the Pacific (Scarff, 1986; 1991; Clapham et al., 2004). Such pelagic calving would appear to be inconsistent with the records of offshore calving grounds in other locales for the other right whale species. Although there have been sightings in Baja California and Hawaii (Herman et al. 1980; NMFS 2004c), migratory patterns and locations of calving grounds are unknown and whales probably spend the summer in high latitude feeding grounds and migrate to more temperate waters for the winter (Carretta et al. 2002). In 2006, critical habitat was designated in the Bering Sea and Gulf of Alaska (NMFS 2006e).

Historical distribution from British Columbia whaling data (1785-1913) is likely relevant to the Washington coast as well. Data show that right whales were present in offshore British Columbia waters during the months of April to October, possibly feeding or migrating to or from sub-tropical calving grounds (Reeves et al. 1985; Nichol et al. 2002). Operating mainly in coastal waters of British Columbia, British Columbia whalers only took seven right whales from 1900 to 1951. The North Pacific Right Whale Recovery Team reports that the last right whale sighting in British Columbia waters was in 1970 by S. Wada while on board a Japanese scoutboat west of the Queen Charlotte Islands. There have been only 13 records of right whales off California since 1955 and the last sighting off the Washington coast was in May 1992 when an individual was seen traveling northward from the Quinault submarine canyon (Rowlett et al. 1994). Rice (1974) stated that, due to a lack of sightings of a cow with a calf in the North Pacific since 1900, the stock was essentially extinct. However, in recent years (1997-2000), right whales have been observed during summer months in the southeastern Bering Sea (Tynan 1999; Leduc et al. 2001; Moore et al. 2000; Tynan et al. 2001; McDonald and Moore 2002). Right whales may be present in winter in extremely low numbers in the Quinault range but are not known to inhabit inland Washington waters; there are no density estimates available for Quinault, Dabob Bay, or Keyport ranges (Appendix A).

Diving Behavior. Dives of 5 to 15 min or even longer have been reported (Winn et al., 1995; Mate et al., 1997; Baumgartner and Mate, 2003). Baumgartner and Mate (2003) found that the average depth of a North Atlantic right whale dive was strongly correlated with both the average depth of peak copepod abundance and the average depth of the bottom mixed layer's upper surface. North Atlantic right whale feeding dives are characterized by a rapid descent from the surface to a particular depth between 262 and 574 ft, remarkable fidelity to that depth for 5 to 14 min and then rapid ascent back to the surface (Baumgartner and Mate, 2003). Longer surface intervals have been observed for reproductively active females and their calves (Baumgartner and Mate, 2003).

Acoustics. North Pacific right whale calls are classified into five categories: (1) up; (2) down-up; (3) down; (4) constant; and (5) unclassified (McDonald and Moore, 2002). The 'up' call is the predominant type (McDonald and Moore, 2002; Mellinger et al., 2004). Typically, the 'up' call is a signal sweeping from about 90 to 150 Hz in 0.7 sec (McDonald and Moore, 2002; Wiggins et al., 2004). Right whales commonly produce calls in a series of 10 to 15 calls lasting 5 to 10 min, followed by silence lasting an hour or more; some individuals do not call for periods of at least 4 hours (McDonald and Moore, 2002). This calling pattern is similar to the 'moan cluster' reported for North Atlantic right whales by Matthews et al. (2001). Vocalization rates of North Atlantic right whales are also highly variable, and individuals have been known to remain silent for hours (Gillespie and Leaper, 2001).

Frequencies of these vocalizations are between 50 and 500 Hz (Matthews et al., 2001; Laurinolli et al., 2003); typical sounds are in the 300 to 600 Hz range with up- and down-sweeping modulations (Vanderlaan et al., 2003). Vanderlaan et al. (2003) found that lower (<200 Hz) and higher (>900 Hz) frequency sounds are relatively rare. Source levels have been estimated only for pulsive calls of North Atlantic right whales, which are 172 to 187 dB, with a reference pressure of one microPascal (µP) at one meter (dB re 1 µPa-m) (Richardson et al., 1995).

Morphometric analyses of the inner ear of right whales resulted in an estimated hearing frequency range of approximately 10 Hz to 22 kHz, based on established marine mammal models (Parks et al., 2004). Research by Nowacek et al. (2004) on North Atlantic right whales suggests that received sound levels of only 133 to 148 dB re 1 µPa-m for the duration of the sound exposure are likely to disrupt feeding behavior. The authors did note, however, that a return to normal behavior within minutes of when the source is turned off would be expected. While some of the upper frequencies approach those of mid-frequency active sonar, the signal is not similar because they were either too low in frequency range or longer and contains a down sweep signal 4500 – 500 Hz.

4.1.5 Sei Whale (*Balaenoptera borealis*)

Stock. Eastern North Pacific

Status. The IWC only considers one stock of sei whales in the North Pacific (Donovan 1991), but some evidence exists for multiple populations (Masaki 1977; Mizroch et al. 1984; Horwood 1987). Sei whales are distributed far out to sea in temperate regions of the world and do not appear to be associated with coastal features. Whaling effort for this species was distributed continuously across the North Pacific between 45- 55°N (Masaki 1977). Two sei whales that were tagged off California were later killed off Washington and British Columbia (Rice 1974) and the movement of tagged animals has been noted in many other regions of the North Pacific. Sei whales are now rare in California waters (Dohl et al. 1983; Barlow 1997; Forney et al. 1995; Mangels and Gerrodette 1994), but were the fourth most common whale taken by California coastal whalers in the 1950s-1960s (Rice 1974). They are extremely rare south of California (Wade and Gerrodette 1993; Lee 1993). Lacking additional information on sei whale population structure, sei whales in the eastern North Pacific (east of longitude 180°) will be considered as a separate stock. The sei whale is listed as endangered under the ESA and as a depleted and strategic stock under the MMPA (Carretta et al., 2005). The IWC designates the entire North Pacific Ocean as one sei whale stock unit (Donovan, 1991), although some evidence exists for multiple stocks (NMFS, 1998; Carretta et al., 2005). For the NOAA stock assessment reports, sei whales within the Pacific exclusive economic zone (EEZ) are divided into three discrete, non-contiguous areas: (1) the Hawaiian stock; (2) California/ Oregon/Washington stock; and (3) the Eastern North Pacific (Alaska) stock (Carretta et al., 2005).

The taxonomy of the baleen whale group formerly known as sei and Bryde's whales is currently confused and highly controversial (see Reeves et al., 2004) for a recent review, also see the Bryde's whale species account below for further explanation).

Abundance and Distribution. Ohsumi and Wada (1974) estimate the pre-whaling abundance of sei whales to be 58,000-62,000 in the North Pacific. Later, Tillman (1977) used a variety of different methods to estimate the abundance of sei whales in the North Pacific and revised this pre-whaling estimate to 42,000. His estimates for the year 1974 ranged from 7,260 to 12,620. All methods depend on using the history of catches and trends in CPUE or sighting rates; there have been no direct estimates of sei whale abundance in the entire (or eastern) North Pacific based on sighting surveys. Only two confirmed sightings of sei whales and 5 possible sightings (identified as sei or Bryde's whales) were made in California, Oregon, and Washington waters during extensive ship and aerial surveys in 1991, 1992, 1993, 1996, and 2001 (Hill and Barlow 1992; Carretta and Forney 1993; Mangels and Gerrodette 1994; VonSaunder and Barlow 1999; Barlow 2003). Green et al. (1992) did not report any sightings of sei whales in aerial surveys of Oregon and Washington. The abundance estimate for California, Oregon, and Washington waters out to 300 nm, based on 1996 and 2001 shipboard surveys, is 56 (CV = 0.61) whales (Barlow 2003). Density of sei whales for the Oregon/Washington stratum in 2005 was $0.0002/km^2$ which is applicable to the QUTR Site year-round (Appendix A). Sei whales are not known to inhabit inland Washington waters; there are no density estimates available for Quinault, Dabob Bay, or Keyport ranges.

Sei whales spend the summer months feeding in the sub-polar higher latitudes and return to the lower latitudes to calve in winter. There is some evidence from whaling catch data of differential migration patterns by reproductive class, with females arriving at and departing from feeding areas earlier than males (Horwood, 1987; Perry et al., 1999). For the most part, the location of winter breeding areas remains a mystery (Rice, 1998; Perry et al., 1999). In the North Pacific, sei whales are thought to occur mainly south of the Aleutian Islands. They are present all across the temperate North Pacific north of 40°N (NMFS, 1998b) and are seen at least as far south as 20°N (Horwood, 1987). In the east, they range as far south as Baja California, Mexico, and in the west, to Japan and Korea (Reeves et al., 1999). As noted by Reeves et al. (1999), reports in the literature from any time before the mid-1970s are suspect, because of the frequent failure to distinguish sei from Bryde's whales, particularly in tropical to warm temperate waters where Bryde's whales are generally more common than sei whales.

Diving Behavior. There are no reported diving depths or durations for Sei whales.

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; source level is not known (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.

4.1.6 Sperm Whale (*Physeter macrocephalus*)

Stock. California/Oregon/Washington

Status. The sperm whale is listed as endangered under the ESA and as a depleted and strategic stock under the MMPA (Carretta et al., 2005). There is no designated critical habitat for this species in the North Pacific. Although many sperm whale populations have been depleted to varying degrees by past whaling activities, sperm whales remain one of the more globally common great whale species. In fact, in some areas, they are actually quite abundant. For example, there are estimated to be about 21,200 to 22,700 sperm whales in the eastern tropical Pacific Ocean (Wade and Gerrodette, 1993).

For management purposes, the IWC has divided the North Pacific into two management regions defined by a zigzag line which starts at 150°W at the equator, is at 160°W between 40° to 50°N, and ends up at 180°W north of 50°N (Donovan, 1991). 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., 2005). The NOAA stock assessment report divides sperm whales within the U.S. Pacific EEZ into three discrete, noncontiguous areas: (1) waters around the Hawaiian Islands, (2) California, Oregon, and Washington waters, and (3) Alaskan waters (Carretta et al., 2005). Sperm whale abundance in the eastern temperate North Pacific is estimated to be 32,100 individuals and 26,300 individuals by acoustic and visual detection methods, respectively (Barlow and Taylor, 2005).

Abundance and Distribution. Barlow and Taylor (2001) estimated 1,407 (CV=0.39) sperm whales along the coasts of California, Oregon, and Washington during summer/fall based on ship line transect surveys in 1993 and 1996. Forney et al. (1995) estimated 892 (CV=0.99) sperm whales off California during winter/spring based on aerial line-transect surveys in 1991-92, but 157 this estimate does not correct for diving whales that were missed and is now more than eight years out of date. The most recent abundance estimate is based on summer/autumn shipboard surveys conducted within 300 nm of the coasts of California, Oregon, and Washington in 1996 (Barlow 1997) and 2001 (Barlow 2003). The combined weighted estimate for the 1996 and 2001 surveys is 1,233 (CV = 0.41) sperm whales (Barlow 2003). Green et al. (1992) report that sperm whales were the third most abundant large whale (after gray and humpback whales) in aerial surveys off Oregon and Washington, but they did not estimate population size for that area. A large 1982 abundance estimate for the entire eastern North Pacific (Gosho et al. 1984) was based on a CPUE method which is no longer accepted as valid by the International Whaling Commission. Recently, a combined visual and acoustic line-transect survey conducted in the eastern temperate North Pacific in spring 1997 resulted in estimates of 24,000 (CV=0.46) sperm whales based on visual sightings, and 39,200 (CV=0.60) based acoustic detections and visual group size estimates (Barlow and Taylor 1998). However, it is not known whether any or all of these animals routinely enter the U.S. EEZ. In the eastern tropical Pacific, the abundance of sperm whales has been estimated as 22,700 (95% C.I.=14,800-34,600; Wade and Gerrodette 1993), but this area does not include areas where sperm whales are taken by drift gillnet fisheries in the U.S. EEZ and there is no evidence of sperm whale movements from the eastern tropical Pacific to the U.S. EEZ. Barlow and Taylor (2001) also estimated 1,640 (CV=0.33) sperm whales off the west coast of Baja California, but again there is no evidence for interchange between these animals and those off California, Oregon and Washington. Clearly, large populations of sperm whales exist in waters that are within several thousand miles west and south of the California, Oregon, and Washington region that is covered by this report; however, there is no evidence of sperm whale movements into this region from either the west or south and genetic data suggest that mixing to the west is extremely unlikely. There is limited evidence of sperm whale movement from California to northern areas off British Columbia, but there are no abundance estimates for this area. The most precise and recent estimate of sperm whale abundance for this stock is; therefore, from the ship surveys conducted in 1996 and 2001 (Barlow 2003). Density for sperm whales from the Olympic Coast-Slope stratum (Forney, 2007) was estimated at 0.0011/km2 (Appendix A), and is applicable on the Quinault range year-round. Sperm whales are not known to inhabit inland Washington waters; density for sperm whales on the Dabob Bay and Keyport ranges is zero.

Diving Behavior. Sperm whales forage during deep dives that routinely exceed a depth of 1,314 ft and 30 min duration (Watkins et al., 2002). Sperm whales are capable of diving to depths of over 6,564 ft 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).

Acoustics. Sperm whales produce short-duration (generally less than 3 sec), broadband clicks. These clicks range in frequency from 100 Hz to 30 kHz, with dominant energy in two bands (2 to 4 kHz and 10 to 16 kHz). Generally, most of the acoustic energy is present at frequencies below 4 kHz, although diffuse energy up to past 20 kHz has been reported (Thode et al., 2002). 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).

The anatomy of the sperm whale's ear indicates that it hears high-frequency sounds (Ketten 1992). Anatomical studies also suggest that the sperm whale has some ultrasonic 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). Auditory brainstem response in a neonatal sperm whale indicated highest sensitivity to frequencies between 5 and 20 kHz (Ridgway and Carder, 2001).

4.1.7 Killer Whale (*Orcinus orca*)

Stock. Southern Resident Stock

Status. In 2003, the Southern Resident population of the Puget Sound region was listed as a "depleted" stock under the MMPA (Krahn et al. 2002). In November 2005, NMFS listed the Southern Resident population as endangered under the ESA (NMFS 2005b) and, in November 2006, NMFS also designated critical habitat for Southern Resident killer whales within 2,500 mi2 (6,475 km2) of marine habitat that includes Haro Strait and the waters around the San Juan Islands, Puget Sound, and the Strait of Juan de Fuca. A number of military operating areas are excluded from this critical habitat designation, including the current Keyport Range Site (NMFS 2006a). However, critical habitat was designated for the waters of the proposed range extension. Killer whales have never been recorded within the Keyport action area and they are expected to be very rare visitors to the area.

<u>Abundance and Distribution</u>. The Southern Resident population is comprised of three pods totaling 90 whales (NMFS 2006e) and typically range between inland waters of Washington and southern Vancouver Island, British Columbia in spring and summer. The Southern Resident population spends much off its time in the region north of Keyport Range Site, especially near the San Juan Islands, the mouth of the Fraser River, and near the southern end of Vancouver Island. Most resident pods leave the area in fall (October- November) and return to the area in spring (May - June). These whales enter nearly all of Puget Sound and specialize in fish prey, in particular salmon (Ford et al. 1998; Saulitis et al. 2000). The population declined by approximately 15% during the 1990s; however in recent years numbers have increased. The causes of the decline in the 1990s are not known, but could include exposure to chemical contaminants, reduced availability of prey resources, and increased human activities. Recent studies of killer whales have shown that these whales are highly contaminated by PCBs (Hayteas and Duffield 2000; Ross et al. 2000; Grant and Ross 2002).

During winter, the Southern Resident killer whales have been documented in the coastal waters off the Queen Charlotte Islands and Vancouver Island to the north, Washington, Oregon, and more recently off the coast of central California (NMFS 2006a). Based on ship-based transect observations and calculated densities (Forney 2007), it is estimated that 13-14 killer whales are likely to occur in the expanded QUTR action area. The majority of these animals are likely to be members of the Offshore population; lesser numbers of Transients and only rarely Southern Residents are expected to occur in the QUTR action area, and then only during winter. Density for killer whales in the OCNMS stratum (Forney, 2007) was estimated at 0.0028/km2 (Appendix A) which is applicable year-round for the Quinault range. This density does not differentiate between killer whale stocks (i.e., it likely includes killer whales from more than one stock).

Density for killer whales in inland waters is more difficult to determine, due to the seasonality and inconsistency of occurrence by both transient and resident pods in those regions. There are no published densities for killer whales in inland waters. Resident killer whales have not been observed in Dabob Bay, but transient pods were observed in Hood Canal for lengthy periods of time in 2003 (January–March) and 2005 (February–June), feeding on harbor seals (London, 2006). To determine density, the maximum number of transient killer whales (11) observed at any one time was divided by the area of Hood Canal (Appendix A), and is applicable for the DBRC for January–June. This density is applicable to either proposed range extension, either north and south or south only, because the killer whale distribution overlaps both areas. Killer whales have occasionally been seen in the Keyport area, but incidence is low and transitory; density is zero for the Keyport range.

<u>Diving Behavior</u>. The maximum depth recorded for free-ranging killer whales diving off British Columbia is about 864 ft (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 (Baird et al., 2003). The longest duration of a recorded dive from a radio-tagged killer whale was 17 min (Dahlheim and Heyning, 1999).

<u>Acoustics</u>. 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). 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).

4.1.8 Steller Sea Lion (*Eumetopias jubatus*)

Stock. Western United States

Status. The Eastern U.S. Stock of Steller sea lions (those east of 144ºW) is listed as threatened and the Western U.S. Stock is listed as Endangered under the U.S. ESA. It is listed as Endangered on the 2006 IUCN Red List of Threatened Species (IUCN 2006) because of "An observed, estimated, inferred or suspected population size reduction of at least 50% over the last 10 years or three generations, whichever is the longer, based on an index of abundance appropriate to the taxon". The most recent population estimates are 38,513 and 44,996 for the Western and Eastern U.S. Stocks, respectively (Angliss and Outlaw 2005).

Abundance and Distribution. Northern or Steller sea lions are found in southern Bering Sea and the North Pacific Ocean, where they occur from the Aleutian and Pribilof Islands into the Gulf of Alaska and south to central California. They are most abundant in the Gulf of Alaska, southeastern Alaska, and British Columbia (Reeves et al. 2002). The overall abundance of Steller sea lions declined from several hundred thousand in the 1970s to approximately 60,000–70,000 by the late 1990s (Reeves et al. 2002). The decline may be attributable to disease, entanglement mortality, and changes in prey availability (Merrick et al. 1987). Long-term shifts in the North Pacific food web associated with commercial whaling may also have been an important factor (Springer et al. 2003). Density was estimated as 0.0096/km^2, which is applicable to the QUTR action area year-round (Appendix A). Steller sea lions are occasionally seen in Puget Sound, but their occurrence is generally rare; density is zero for the Dabob Bay and Keyport ranges for all months.

Steller sea lions aggregate on rocky and gravel beaches throughout the year. Small rookeries exist in California, Oregon, and British Columbia, but the main rookeries are located along the coast of the Gulf of Alaska and in the Aleutian Islands (Reeves et al. 1992). The rookeries off southern Oregon are located along the coast at Rogue and Orford reefs near 42º25' and 42º45'N and 124º30'W, respectively (Bonnell et al. 1992). Counts of adults and juveniles in Oregon have shown a gradual increase from 1486 in 1976 to 3648 in 2001 (Angliss and Outlaw 2005).

Diving Behavior. Steller sea lions in Alaska feed on walleye pollock, as well as herring, cod, salmon and cephalopods in other areas (Reeves et al. 2002). They feed predominantly within 30 km of the coastal rookeries (Bonnell et al. 1992). Steller sea lions typically inhabit coastal waters when feeding and migrating. During surveys off the coasts of Oregon and Washington, Bonnell et al. (1992) noted that 89% of sea lions occurred over the shelf at a mean distance of 21 km from the coast, with the farthest sighting ~40 km from shore; all sightings occurred near or in waters <200 m deep.

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 Non-Endangered or Threatened Species in the NAVSEA NUWC Keyport Range Complex Extension

4.2.1 Minke Whale (*Balaenoptera acutorstrata*)

Stock. California/Oregon/Washington

Status. The minke whale is not listed as endangered under the ESA and is not a depleted or strategic stock under the MMPA (Carretta et al., 2005). The IWC recognizes three stocks of minke whales in the North Pacific: one in the Sea of Japan/East China Sea, one in the rest of the western Pacific west of 180°N, and one in the remainder of the Pacific (Donovan, 1991). For the NOAA stock assessment report, there are three stocks of minke whales within the U.S. Pacific EEZ: (1) a Hawaiian stock; (2) a California/Oregon/Washington stock; and (3) an Alaskan stock (Carretta et al., 2005).

Abundance and Distribution. Minke whales are distributed in polar, temperate, and tropical waters (Jefferson et al., 1993); they are less common in the tropics than in cooler waters. Minke whales are present in the North Pacific from near the equator to the Arctic (Horwood, 1990). The summer range extends to the Chukchi Sea (Perrin and Brownell, 2002). In the winter, minke whales are found south to within 2° of the equator (Perrin and Brownell, 2002). The distribution of minke whale vocalizations (specifically, “boings”) suggests that the winter breeding grounds are the offshore tropical waters of the North Pacific Ocean (Rankin and Barlow, 2003). There is no obvious migration from low-latitude, winter breeding grounds to high-latitude, summer feeding locations in the western North Pacific, as there is in the North Atlantic (Horwood, 1990); however, there are some monthly changes in densities in both high and low latitudes (Okamura et al., 2001). In the northern part of their range, minke whales are believed to be migratory, whereas they appear to establish home ranges in the inland waters of Washington and along central California (Dorsey et al., 1983) and exhibit site fidelity to these areas between years (Borggaard et al., 1999).

No estimates have been made for the number of minke whales in the entire North Pacific. The number of minke whales is estimated as 1,015 (CV = 0.73) based on ship surveys in 1996 and 2001 off California Oregon and Washington (Barlow 2003). Minke whales were sighted offshore Washington and Oregon in both 1996 and 2001 (Appler et al., 2004; Barlow, 2003), but were not sighted during CSCAPE 2005 surveys conducted in June (Forney, 2007). Density of minke whales from surveys conducted offshore Washington and Oregon in 2001 was 0.0004/km^2 Appendix A), which is applicable to the Quinault region year-round. Density for minke whales on the Dabob Bay and Keyport ranges is zero. Minke whales have been sighted in Hood Canal (Angell and Balcomb, 1982) and a few strandings have been recorded (Norman et al., 2004), but they are infrequent visitors.

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).

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.

4.2.2 Gray Whale (*Eschrichtius robustus*)

Stock. California/Oregon/Washington Offshore

Status. The world population of gray whales reached approximately 22,000 in 1994 and was subsequently removed from the U.S. Endangered Species List. By 1997-98, the population had reached a peak of approximately 26,000 individuals (Rugh et al. 1999). The 2001 population estimates for eastern gray whale are about 17,000, a marked decline from the peak in 1997-98, suggesting possible food limitation on their summering grounds in the Bering Sea (Moore et al. 2001).

Abundance and Distribution. Gray whales inhabit shallow coastal waters of the northeastern Pacific, from Baja California north to Arctic Alaska (a separate small remnant stock of gray whales also ranges in the northwestern Pacific). The current estimate for the Eastern North Pacific stock of gray whales is 18,813 (Angliss and Outlaw 2007), which is based on a census conducted during the southbound migration in 2001-02. Gray whales from the Eastern North Pacific stock undertake a well-documented migration from winter calving lagoons in Baja California to summer feeding areas in the Bering and Chukchi seas (Swartz et al. 2006). The migration route is primarily near shore in shallow water, although gray whales have been documented swimming offshore near the Channel Islands in the Southern California Bight. Green et al. (1995) noted that the migration corridor along Oregon and Washington expanded to approximately 43 km in some locations. In addition to the Bering and Chukchi sea feeding areas, gray whales are known to feed opportunistically at several locations along the migratory route (e.g., Oregon; Newell and Cowles 2006), and several whales remain on these opportunistic feeding grounds throughout the year. The Pacific Coast Feeding Aggregation, covering an area stretching from northern California to southeast Alaska, was estimated at 261-298 whales. The estimate for Oregon to British Columbia (excluding Alaska and California) was 197-256 whales. Gray whales would; therefore, likely be present in the near shore regions of the QUTR Site on a year round basis. The year-round density of gray whales in QUTR Action Area is 0.003/km^2. Migrating gray whales do not spend much time in the area of QUTR and typically pass through in a day or less. As a result, the density of migrants is usually zero. Gray whale occurrence within the Keyport and DBRC Action Areas is expected to be very rare, with a density of zero.

Gray whales are seen annually in northern Puget Sound, particularly the waters around Whidbey Island. They are occasionally seen in Hood Canal, and there were several recorded gray whale strandings in that area (Norman et al. 2004). A gray whale stranded at the Kitsap Navy Base in Bremerton in May 2005 (Cascadia Research 2005). These occasional sightings and strandings indicate that while gray whales inhabit the inland waters of Washington State, they do not occur in high enough numbers to permit density to be calculated; density for gray whales on the DBRC and Keyport Range sites is zero.

Diving Behavior. 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).

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).

4.2.3 Dwarf and Pygmy Sperm Whale (*Kogia* sp.)

Stock. California/Oregon/Washington

Status. The difficulty in identifying pygmy and dwarf sperm whales is exacerbated by their avoidance reaction towards ships and change in behavior towards approaching survey aircraft (Würsig et al., 1998). Based on the cryptic behavior of these species and their small group sizes (much like that of beaked whales), as well as similarity in appearance, it is difficult to identify these species in sightings at sea. Neither species of *Kogia* is listed as endangered under the ESA or considered depleted under the MMPA.

Abundance and Distribution. Dwarf and pygmy sperm whales are found in tropical and warm-temperate waters worldwide. They are often confused with each other and often considered together as members of the same genus, *Kogia*. They prefer deep water and feed over the continental shelf where they feed on small fish, deep-sea shrimps, and squid. They are rarely observed at sea and little is known of their biology. The most recent stock estimate for the California/Oregon/Washington stock of *Kogia* sp. was 247 (Carretta et al. 2007). There was one sighting of *Kogia* offshore Oregon/Washington in 1996, no sightings in 2001 (Barlow 2003) and no sightings in 2005 (Forney 2007). Density of *Kogia* was estimated as 0.0015/km^2 based on surveys conducted in 1996 (Barlow 2003); this estimate is applicable to the QUTR Site from May-October. There are no density estimates for the Dabob Bay or Keyport ranges Appendix A). Both species of *Kogia* generally occur in waters along the continental shelf break and over the continental slope (e.g., Baumgartner et al., 2001; McAlpine, 2002; Baird, 2005).

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).

Acoustics. There is no information 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).

4.2.4 Baird's Beaked Whale (*Becardius bairdii*)

Stock. California/Oregon/Washington

Status. The Baird's beaked whale is not listed as endangered under the ESA and is not a depleted or strategic stock under the MMPA (Carretta et al., 2007).

Abundance and 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). Baird's beaked whales are infrequently encountered along the continental slope and throughout deep waters of the eastern North Pacific (Forney et al. 1994; Barlow et al. 1997). No sightings were made during the 1998–1999 NMFS surveys offshore of San Clemente (Carretta et al. 2000). Population size for the California/Oregon/Washington Stock is estimated to be 228 (CV=0.51) individuals (Carretta et al. 2007). Based on the 2005 survey data (Forney 2007) the density for Baird's beaked whales is estimated at 0.0027/km^2 for the QUTR Action Area year round. Baird's beaked whales have not been sighted nor have strandings been recorded in Puget Sound; density for the Dabob Bay and Keyport ranges is zero (Appendix A).

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 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. Dives ranged from at least 13 min (lost dive recorder during the dive) to a maximum of 68 min (Baird et al. 2006).

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). 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).

Beaked whale ears are predominantly adapted to hear ultrasonic frequencies (MacLeod 1999). Recent information on the hearing abilities of beaked whales (Blaineville's, Cuvier's and Gervais' beaked whales) show that they are most sensitive from 40 to 80 kHz with an overall range of 5 to 80 kHz (Johnson et al. 2004; Zimmer et al. 2005; Cook et al. 2006).

4.2.5 Mesoplodonts (incl. Hubb's and Stejneger's beaked whales) (*Mesoplodon* sp.)

Stock. California/Oregon/Washington

Status. For California, Oregon, and Washington waters, neither Hubb's or Stejneger's beaked whale is listed as endangered under the ESA and is not a depleted or strategic stock under the MMPA (Carretta et al., 2007).

Abundance and Distribution. Stejneger's beaked whale.—This species occurs in subarctic and cool temperate waters of the North Pacific Ocean (NPO) (Mead 1989). In the NPO, it is distributed from Alaska to southern California (Mead et al. 1982; Mead 1989). However, most records are from Alaskan waters, and the Aleutian Islands appear to be its center of distribution. Small groups have been known to strand at the Aleutian Islands (Mead 1989). This species occurs in groups of 3 to 4, ranging to ~15 (Reeves et al. 2002).

Hubb's beaked whale.—This species occurs in temperate waters of the North Pacific (Mead 1989). Most of the records are from California, but it has been sighted as far north as Prince Rupert, British Columbia (Mead 1989). Strandings are known from Washington/Oregon (Houston 1990, Green et al. 1992). The distribution of the species appears to be correlated with the deep subarctic current (Mead et al. 1982). Hubb's beaked whales are often killed in drift gillnets off California (Reeves et al. 2002).

The different mesoplodont species are difficult to distinguish in the field, and are most often categorized during sighting surveys and; therefore, in density and population estimates, as Mesoplodon sp. Almost everything that is known regarding most of those species has come from stranded animals (Pitman 2002). They are all thought to be deep-water animals that tend to inhabit shelf-edge habitat associated with underwater canyons, and are only rarely seen over the continental shelf (Waring et al. 2001). Typical group sizes range from 1 to 6 (Pitman 2002). The habits of these species, combined with recent (1996) recorded sightings offshore Washington, indicate that they may be likely to occur in the Quinault range. For California, Oregon, and Washington waters, Barlow (1997) estimated an abundance of 3,738 mesoplodont beaked whales of unknown species. In 1996, the estimated abundance of mesoplodont beaked whales was 2169 for Oregon and Washington, but in 2001 it was zero (Barlow 2003). Barlow (2003) reported a density of 0.0067/km2 for Oregon/Washington and densities up to 0.0027/km2 for 2005 (Forney 2007). Density for the Oregon and Washington stratum (Forney, 2007) for mesoplodont beaked whales was calculated as 0.0027/km^2 (Appendix A), which is applicable for *Mesoplodon* sp. in the Quinault range year round. Beaked whales have not been sighted nor have strandings been recorded in Puget Sound; density for the Dabob Bay and Keyport ranges is zero.

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 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. 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 and mean duration of 46.5 min for Baird’s beaked whales.

The depth distribution for Blainville’s beaked whales (and applicable to *Mesoplodon* sp) based on best available information from Tyack et al. (2006b) is: 26% at <2 m, 41% in 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 >835 m.

Acoustics. Rankin and Barlow (2007) reported on the vocalizations of Blaineville’s beaked whales in Hawaii that included four mid frequency sounds: a frequency-modulated whistle and three frequency and amplitude modulated pulsed sounds within the range of 6 and 16 kHz. 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 156 to 450 msec (Lynn and Reiss, 1992; Marten, 2000).

MacLeod (1999) suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for pulse sounds, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Cuvier’s beaked whale’s echolocation clicks were recorded at frequencies from 20 to 70 kHz (Zimmer et al. 2005).

There is no hearing information on these beaked whale acoustics but they may be similar to other beaked whales. 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). The Gervais beaked whale was most sensitive from 40 to 80 kHz (Cook et al. 2006).

4.2.6 Killer Whale (*Orcinus orca*)

Stock. Transient

Status. The killer whale is not listed as endangered under the ESA and is not a depleted or strategic stock under the MMPA. Population trends and status of this stock are currently unknown.

Abundance and Distribution. There are four stocks of killer whales in the north Pacific that can be found at least seasonally in inland and offshore waters of Washington State, but who differ in feeding preferences, acoustics and genetics; each of these stocks appears to be reproductively isolated from the others. The Eastern North Pacific Southern Resident (listed as Endangered, See 4.1.7) stock feeds primarily on fish, and ranges from the inland waters of Washington and southern British Columbia to near shore waters as far north as the Queen Charlotte Islands of British Columbia and south to at least central California (Wiles 2004). The Eastern North Pacific Northern Resident stock also feeds on fish, but its range is primarily the inland waters of British Columbia. This stock, which numbers approximately 16 pods, will occasionally venture into the Strait of Juan de Fuca and offshore the Olympic Peninsula of Washington (Wiles 2004). The Eastern North Pacific Offshore Stock is found year round ranging from offshore California north to offshore Washington and occasionally British Columbia, and also apparently feeds primarily on fish. The current stock estimate is 466 animals; 211 have been photo-identified (Carretta et al. 2007). The West Coast Transient stock ranges year round from Alaska to California, and feeds primarily on other marine mammals. The minimum estimate based on photo ID for that population is 314.

Transient killer whales are known to occur throughout Puget Sound but have not been recorded within the Keyport action area and are expected to be very rare visitors to the area, with a density of zero. Transients are uncommon visitors to Hood Canal. In 2003 and 2005, small groups of transient killer whales (6 – 11 individuals per event) visited Hood Canal to feed on harbor seals and remained in the area for significant periods of time (59 – 172 days) between the months of January and July. Based on this data, the density for Transient killer whales in the DBRC Action Area for January to June is 0.038/km^2. As stated previously the density in the QUTR Action Area does not differentiate between killer whale stocks. Therefore, Transient killer whale density for the QUTR Action Area is accounted for in the Southern Resident killer whale density.

Diving Behavior. The maximum depth recorded for free-ranging killer whales diving off British Columbia is about 864 ft (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 (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. 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). 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).

4.2.7 Risso's Dolphin (*Grampus griseus*)

Stock. California/Oregon/Washington

Status. The Risso's dolphin is not listed as endangered under the ESA and is not a depleted or strategic stock under the MMPA (Carretta et al., 2005). There is no information on the population trend of Risso's dolphins.

Abundance and 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. Based on sighting patterns from recent aerial and shipboard surveys conducted in these three states during different seasons, animals found off California during the colder water months are thought to shift northward into Oregon and Washington as water temperatures increase in late spring and summer (Green et al. 1992). The southern end of this population's range is not well-documented, but on a recent joint U.S./Mexican ship survey, Risso's dolphins were sighted off northern Baja California, and a conspicuous 500 nm gap was present between these animals and Risso's dolphins sighted south of Baja California and in the Gulf of California (Mangels and Gerrodette 1994). Thus this population appears distinct from animals found in the eastern tropical Pacific and the Gulf of California. Although Risso's dolphins are not restricted to U.S. waters, cooperative management agreements with Mexico exist only for the tuna purse seine fishery and not for other fisheries which may take this species (e.g. gillnet fisheries). For the MMPA stock assessment reports, Risso's dolphins within the Pacific U.S. Exclusive Economic Zone are divided into two discrete, non-contiguous areas: 1) waters off California, Oregon and Washington, and 2) Hawaiian waters. There were several Grampus sighted offshore Washington during vessel surveys conducted in 2001 (Appler et al., 2004), although none were sighted during surveys in 2005 (Forney, 2007); the closest sighting was off north-central Oregon. Density for Risso's dolphins in the Oregon and Washington stratum (Forney, 2007) was estimated at 0.002/km2 (Appendix A), which is applicable year-round for the Quinault range. Risso's dolphins are not known to inhabit inland Washington waters; density for the Dabob Bay and Keyport ranges is zero.

Diving Behavior. Risso's dolphins may remain submerged on dives for up to 30 min (Kruse et al., 1999). Cephalopods are the primary prey (Clarke, 1996).

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 source levels were up to 216 dB re 1 μPa-m (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).

4.2.8 Pacific White-Sided Dolphin (*Lagenorhynchus obliquidens*)

Stock. California/Oregon/Washington

Status. Pacific white-sided dolphins are endemic to temperate waters of the North Pacific Ocean and are common both on the high seas and along continental margins in shelf and slope waters (Carretta et al.

2002). 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.

Abundance and Distribution. The size of the California/Oregon/Washington Stock is estimated to be 59,274 (CV=0.50) individuals (Carretta et al. 2007).The abundance along Washington and Oregon in 1992 was estimated to be 23,400 animals (Green et al. 1992); however, more recent estimates are considerably lower: 8,683 in 1996, 10,934 in 2001 (Barlow 2003), and 7,645 in 2005 (Forney 2007). 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). There were several sightings of this species during vessel surveys conducted in 2005 (Forney, 2007). Density calculated for the OCNMS stratum from 2005 surveys was 0.1929/km2 (Appendix A), which is applicable to the Quinault range from May–October. This species is not known to occur in Puget Sound; density for the Dabob Bay and Keyport ranges is zero.

Diving Behavior. Pacific white-sided dolphins in the eastern North Pacific feed primarily on epipelagic fishes and cephalopods (e.g., Schwartz et al. 1992; Heise 1997; Brownell et al. 1999; Morton 2000). 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 120 m. The majority of foraging dives last less than 15 to 25 sec (Heise 1997).

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, while the lowest measurable sensitivities were 145 dB at 100 Hz and 131 dB at 140 kHz. Below 8 Hz and above 100 kHz, this dolphin's hearing was similar to that of other toothed whales.

4.2.9 Short-beaked Common Dolphin (*Delphinus delphinus*)

Stock. California/Oregon/Washington

Status. The short-beaked common dolphin is not listed under the ESA, and the California/Oregon/Washington Stock is not considered depleted or strategic under the MMPA. 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). They feed on squid and small schooling fish.

Abundance and Distribution. Barlow (2003) estimated a total population of short-beaked common dolphins present in Oregon and Washington waters during the July–November period at 6,316 during 1996 and 398 during 2001. The population of short-beaked common dolphins during the same period in 2005 was estimated at 10,601 (Forney 2007). Therefore, although short-beaked common dolphins can be expected to occur in the QUTR action area, their presence at any given time would be uncommon, and the density is 0.0012/km^2 for May to October. This species is not known to occur in Puget Sound; density is zero for the Dabob Bay and Keyport ranges. However, when they are present, they are likely to occur in groups of tens, hundreds, or even thousands of animals (Appendix A).

Diving Behavior. There are limited direct measurements of short-beaked common dolphines but dives to >200 meters possible, but most in the range of 9-50 m based on a study on one tagged individual tracked off San Diego (Evans 1994).

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 were approximately 180 dB 1 µPa-m (Fish and Turl, 1976). Oswald et al. (2003) found that short-beaked common dolphins in the ETP 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.

4.2.10 Striped Dolphin (*Stenella coeruleoalba*)

Stock. California/Oregon/Washington

Status. The striped dolphin is not listed as endangered under the ESA and is not a depleted or strategic stock under the MMPA (Carretta et al., 2005). There is no information on the population trend of striped dolphins.

Abundance and Distribution. Striped dolphins are distributed world-wide in tropical and warm-temperate pelagic waters. On recent shipboard surveys extending about 300 nm offshore of California, they were sighted within about 100-300 nm from the coast. No sightings have been reported for Oregon and Washington waters, but striped dolphins have stranded in both states (Oregon Department of Fish and Wildlife, unpublished data; Washington Department of Fish and Wildlife, unpublished data). Striped dolphins are also commonly found in the central North Pacific, but sampling between this region and California has been insufficient to determine whether the distribution is continuous. Based on sighting records off California and Mexico, striped dolphins appear to have a continuous distribution in offshore waters of these two regions (Perrin et al. 1985; Mangels and Gerrodette 1994). No information on possible seasonality in distribution is available, because the California surveys which extended 300 nm offshore were conducted only during the summer/fall period. Although striped dolphins are not restricted to U.S. waters, cooperative management agreements with Mexico exist only for the tuna purse seine fishery and not for other fisheries which may take this species (e.g. gillnet fisheries). Therefore, the management stock includes only animals found within U.S. waters. For the MMPA stock assessment reports, striped dolphins within the Pacific U.S. EEZ are divided into two discrete, non-contiguous areas: 1) waters off California, Oregon and Washington, and 2) waters around Hawaii.

Barlow (2003) estimated a population size of 64 animals off the entire coast of Oregon and Washington during 1996. Therefore, based on the 1996 data, the density for the QUTR Action Area is 0.0002/km^2 for May to October. There are no density estimates available for the Dabob Bay or Keyport ranges (Appendix A).

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 109 to 383 fathoms 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).

4.2.11 Northern Right Whale Dolphin (*Lissodelphis morealis*)

Stock. California/Oregon/Washington

Status. The northern right whale dolphin is not listed under the ESA, and the California/ Oregon/Washington Stock is not considered depleted or strategic. Population size of the California/Oregon/Washington Stock is estimated to be 20,362 (CV=0.26) individuals (Carretta et al. 2007).

Abundance and Distribution. Northern right whale dolphins are endemic to temperate waters of the North Pacific Ocean and are commonly seen both on the high seas and along continental margins in shelf and slope waters (Carretta et al. 2002). From sighting patterns it is suspected that the northern right whale dolphins residing along the coast of the continental U.S. migrate north beginning in late spring and summer and spend the colder months off the coast of California (Green et al. 1992; Forney et al. 1995). The abundance along Washington and Oregon in 1996 was estimated to be 5,026, 10,190 in 2001 (Barlow 2003), and 7,723 in 2005 (Forney 2007). Based on recent survey data (Forney 2007) the density is estimated at 0.0419/km^2 for the QUTR Action Area year round (Appendix A). This species is not known to occur in Puget Sound; density for the Dabob Bay and Keyport ranges is zero.

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 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 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 (0-400 m) waters. Prey distribution during the day is estimated at 400-700 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). There is no published data on the hearing abilities of this species.

4.2.12 Dall's Porpoise (*Phocoenides dalli*)

Stock. California/Oregon/Washington

Status. Dall's porpoise is not listed as endangered under the ESA and is not a depleted or strategic stock under the MMPA. The California/Oregon/Washington stock is currently estimated at 98,617 animals (Carretta et al. 2007).

Abundance and Distribution. Dall's porpoise is widely distributed in cool temperate waters of the North Pacific from the U.S.–Mexico border north to the Bering Sea, ranging from ~32ºN to 65ºN (Reeves et al. 2002). Dall's porpoise usually occurs in small groups of 2–12, characterized by fluid associations (Reeves et al. 2002). It is a common bowrider, although mothers with calves appear to avoid vessels. Calves are born between early spring and early fall, with most born from June to August. A high percentage of the Dall's porpoise diet consists primarily of small schooling fish, such as herring and hake, squid, and other species associated with the DSL (Reeves et al. 2002).

Off Oregon and Washington, it is widely distributed over shelf and slope waters, with concentrations near shelf edges, but is also commonly sighted in pelagic offshore waters (Morejohn 1979; Green et al. 1992; Carretta et al. 2002). Combined results of various surveys out to ~550 km offshore indicate that the distribution and abundance of Dall's porpoise varies between seasons and years. North–south movements are believed to occur between Oregon/Washington and California in response to changing oceanographic conditions, particularly temperature and distribution and abundance of prey (Green et al. 1992, 1993; Mangels and Gerrodette 1994; Barlow 1995; Forney and Barlow 1998; Buchanan et al. 2001). The abundance and distribution of Dall's porpoise off Oregon/Washington also appears to shift from slope to shelf waters during the fall as it pursues schooling fish and squid; during the winter, they move offshore again to slope waters (Fiscus and Niggol 1965; Green et al. 1992).

Dall's porpoise are rare and very rare in the Keyport and DBRC Action Areas, respectively. The density in these areas is zero. Density of Dall's porpoise in the Olympic Coast-Slope stratum in 2005 (Forney 2007) was estimated at $0.1718/km^2$, which is applicable to the QUTR Site year-round. Their use of inland Washington waters, however, is mostly limited to the Strait of Juan de Fuca; density for the Dabob Bay and Keyport ranges is zero (Appendix A).

Encounter rates reported by Green et al. (1992) during aerial surveys off Oregon/Washington were highest in the fall (8.21/1000 km), lowest during the winter (4.79), and intermediate during spring and summer (5.53 and 6.39, respectively). Encounter rates during the summer were similarly high in slope and shelf waters (6.66 and 6.84/1000 km), and somewhat lower in offshore waters (4.56).

Diving Behavior. Dall's porpoises feed primarily on small fish and squid (Houck and Jefferson 1999). 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).

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.

4.2.13 Harbor Porpoise (*Phocoena phocoena*)

Stock. Oregon/Washington

Status. The harbor porpoise is not listed under the ESA, but it is listed as Vulnerable on the 2006 IUCN Red List of Threatened Species (IUCN 2006) because of "An observed, estimated, inferred or suspected population size reduction of at least 20% over the last 10 years or three generations, whichever is the longer, based on a decline in area of occupancy, extent of occurrence and/or quality of habitat, and actual or potential levels of exploitation", and is listed in CITES Appendix II (UNEP-WCMC 2006)

Abundance and Distribution. The harbor porpoise inhabits shallow coastal and inland waters (Carretta et al. 2002; Reeves et al. 2002). Along the USWC, it ranges from Point Barrow, Alaska, to central California (Carretta et al. 2002). Harbor porpoises tend to be solitary but are very mobile; they have home range sizes of thousands of square miles and often travel many miles per day (Reeves et al. 2002).Based on year-round surveys spanning coastal to offshore waters of Oregon/Washington, Green et al. (1992) reported that 96% of harbor porpoise sightings occurred in coastal waters <100 m deep, with a few sightings made on the slope near the 200-m isobath. During summer, the reported encounter rates decreased notably from inner shelf to offshore waters. In slope and offshore waters from Newport to Cape Blanco, Oregon, encounter rates were 1.0 and 0.0/1000 km, respectively. Summer encounter rates in inner and outer shelf waters were considerably higher at 32.7 and 24.7/1000 km, respectively (Green et al. 1992). The corrected abundance estimate for the harbor porpoise off Oregon/Washington out to water depths of 200 m is 39,586 (Laake et al. 1998; Carretta et al. 2006). Based on this data harbor porpoise are considered abundant with a density of $2.86/km^2$ in the QUTR Action Area. Harbor porpoise are occasionally seen in Hood Canal and elsewhere in southern Puget Sound; however, their occurrence there is rare. Density for Dabob Bay and Keyport ranges is zero (Appendix A).

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).

4.2.14 Northern Fur Seal (*Callorhinus ursinus*)

Stock. Eastern Pacific

Status. The northern fur seal is not listed as endangered under the ESA and is not a depleted or strategic stock under the MMPA. The northern fur seal is endemic to the north Pacific. Breeding sites are located in the Pribilof Islands (over 70% of the world population) and Bogoslof Island in the Bering Sea, Kuril and Commander Islands in the northwest Pacific, and San Miguel Island in the southern California Bight. Abundance of the Eastern Pacific Stock has been decreasing at the Pribilof Islands since the 1940s although increasing on Bogoslof Island. The stock is currently estimated to number 721,935 (NMFS 2006a). The San Miguel Island stock is much smaller, estimated at 7,784 (Carretta et al. 2007); this stock is believed to remain predominantly offshore California year round.

Abundance and Distribution. In the NPO, northern fur seals occur from southern California to the Bering Sea. During the breeding season, 74% of the worldwide population inhabits the Pribilof Islands in the southern Bering Sea (Lander and Kajimura 1982). A small percentage of seals breed at San Miguel Island off southern California. Outside of the breeding season, fur seals may haul out at other sites in Alaska, British Columbia, and areas along the USWC (Fiscus 1983). The population estimate for San Miguel Island, California, is 7784 (Carretta et al. 2006); there are about 1.2 million worldwide (Reeves et al. 2002).

Adult females and males occur onshore at different but overlapping times during the breeding season. Adult males usually come ashore in May–August and may sometimes be present until November, and adult females are found ashore from June to November (Carretta et al. 2006). After reproduction, they spend the next 7–8 months feeding at sea (Roppel 1984).

Adult females and pups from the Pribilof Islands migrate to Oregon and California offshore waters, but adult males only migrate as far south as the Gulf of Alaska (Kajimura 1984). Bonnell et al. (1992) noted the presence of northern fur seals year-round off Oregon and Washington, with the greatest numbers (87%) occurring in January–May. The highest densities were seen in the Columbia River plume and in deep offshore waters (>2000 m) off central and southern Oregon. Northern fur seals were seen as far out from the coast as 185 km, the offshore limit of the survey, and numbers increased with distance from land; they were 5–6 times more abundant in offshore waters than over the shelf or slope. In June–December, offshore densities generally were <0.01/km2, ranging up to a maximum of 0.1/km2 (Bonnell et al. 1992). The densities for the QUTR Action Area are 0.090/km^2 (warm season) and 0.117/km^2 (cold season). Northern fur seals are rarely sighted in Puget Sound; density for the Dabob Bay and Keyport ranges is zero for all months.

Diving Behavior. Northern fur seals feed on nearshore and pelagic squid and fish, and are solitary when feeding at sea (Reeves et al. 2002). During feeding, they mostly make shallow dives of up to 50 m, but dives can reach depths of 250 m (Reeves et al. 2002).

4.2.15 California Sea Lion (*Zalophus californianus*)

Stock. United States

Status. The California sea lion is not listed as endangered under the ESA and is not a depleted or strategic stock under the MMPA

Abundance and Distribution. The US stock of California sea lions breeds in the Channel Islands in the southern California Bight. The population is currently estimated at 237,000 to 244,000, based on pup counts conducted in 2001 (Carretta et al. 2007). There are two additional stocks of California sea lions; one breeds on islands off the west coast of Baja California, while the other breeds on islands in the Gulf of California. There is some mixing between all three stocks during the non-breeding season, although the extent is unknown. Pupping and breeding occur from May-July. Females generally do not migrate as far north as males, remaining closer to the rookeries. Adult male California sea lions will migrate north after the breeding season (August-April) to near shore waters of Washington, Oregon and British Columbia, and a few immature males will remain in northern feeding areas year round. Jeffries et al. (2000) identified 46 haulout locations used by California sea lions along the Washington/southern British Columbia coast and inland waterways. Most haulouts were in southern Puget Sound, with two large (100-500 animals each) haulouts located along the outer coast in the Split Rock area.

California sea lions are expected to be common visitors to the DBRC action area. The density of California sea lions in the DBRC Action Area is 0.052/km^2 for the cold season. Density of California sea lions in the QUTR action area is estimated at 0.283/km^2. This density is applicable only to the very near shore waters of Washington State from August to April. California sea lions are rarely seen near Keyport; density is zero for the Keyport range for all months (Appendix A).

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 (Richardson et al. 1995). The male barks have most of their energy at less than 1 kHz (Schusterman et al. 1967). 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 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 100 Hz and 2,000 Hz for threshold testing at 2,000 Hz; the duration of exposure was 20 min.

4.2.16 Northern Elephant Seal (*Mirounga angustirostris*)

Stock. California Breeding

Status. The northern elephant seal is not listed as endangered under the ESA and is not a depleted or strategic stock under the MMPA (Carretta et al., 2005).

Abundance and Distribution. The northern elephant seal population has recovered dramatically after being reduced to several dozen to perhaps no more than a few animals in the 1890s (Bartholomew and Hubbs, 1960; Stewart et al., 1994). Although movement and genetic exchange continues between rookeries, most elephant seals return to their natal rookeries when they start breeding (Huber et al., 1991). The population size has to be estimated since all age classes are not ashore at any one time of the year (Carretta et al., 2005). There is a conservative minimum population estimate of 60,547 elephant seals in the California stock (Carretta et al., 2005). Based on trends in pup counts, abundance in California is increasing by around 6 percent annually, but the Mexican stock is evidently decreasing slowly (Stewart et al., 1994; Carretta et al., 2005).

The northern elephant seal is endemic to the North Pacific Ocean, occurring almost exclusively in the eastern and central North Pacific. However, vagrant individuals do sometimes range to the western North Pacific. The most far-ranging individual appeared on Nijima Island off the Pacific coast of Japan in 1989 (Kiyota et al., 1992). This demonstrates the great distances that these animals are capable of covering.

During the breeding period (December-February), offshore occurrence would be limited to immature (non-breeding) seals which is estimated at 37,630 immature seals. Density for December-February was calculated as 37,630 seals/2,032,000 km^2, or 0.019/km^2 and applies to the entire QUTR Site. In March-April, offshore occurrence would include adult females and juveniles minus the number of animals expected to not be foraging offshore due to molting, for a total of 53,180 and a calculated density of 0.026/km^2. From May-July, offshore occurrence would include adult females, juveniles, and pups of the year minus the number of animals expected to not be foraging offshore due to molting for a total of 76,256 and a calculated density of 0.038/km^2. In August-November, offshore occurrence would include all elephant seals except adult males, and there is no molting taking place so the estimated abundance offshore would be 95,320. Therefore, density in the QUTR Site in August-November would be 0.047/km^2 (Appendix A).

Diving Behavior. Feeding habitat is mostly in deep, offshore waters of warm temperate to sub-polar zones (Stewart and DeLong, 1995; Stewart, 1997; Le Boeuf et al., 2000). Some seals will move into subtropical or tropical waters while foraging (Stewart and DeLong, 1995).

Both sexes routinely dive deep (up to 4,500 ft) (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 (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) 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 (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).

4.2.17 Harbor Seal (*Phoca vitulina richardsi*)

Stock. Oregon/Washington Coast

Status. The harbor seal is not listed as endangered under the ESA and is not a depleted or strategic stock under the MMPA (Carretta et al., 2005).

Abundance and Distribution. Historical levels of harbor seal abundance in Oregon and Washington are unknown. The population apparently decreased during the 1940s and 1950s due to state-financed bounty programs. Approximately 17,133 harbor seals were killed in Washington by bounty hunters between 1943 and 1960 (Newby 1973). More than 3,800 harbor seals were killed in Oregon between 1925 and 1972 by bounty hunters and a state-hired seal hunter. The population remained relatively low during the 1960s but, since the termination of the harbor seal bounty program and with the protection provided by the passage of the MMPA in 1972, harbor seal counts for this stock have increased from 6,389 in 1977 to 16,165 in 1999 (Jeffries et al. 2003; ODFW, unpubl. data). Between 1983 and 1996, the annual rate of increase for this stock was 4%, with the peak count of 18,667 seals occurring in 1992. From 1991 to 1996, however, this stock declined 1.6% (t=3.25; p=0.083) annually (Jeffries et al. 1997), which may indicate that this population has exceeded equilibrium levels. Analyzing only the Oregon data (average annual rate of increase was 0.3% from 1988-96) indicates that the Oregon segment of the stock may be approaching equilibrium (Brown 1997). The Oregon/Washington Coast harbor seal stock increased at an annual rate of 7% from 1983 to 1992 and at 4% from 1983 to 1996 (Jeffries et al. 1997). Because the population was not at a very low level by 1983, the observed rates of increase may underestimate the maximum net productivity rate (RMAX). When a logistic model was fit to the Washington portion of the 1975-1999 abundance data, the resulting estimate of RMAX was 18.5% (95% CI = 12.9-26.8%) (Jeffries et al. 2003). This value of RMAX is higher than the default pinniped population growth rate value of 12%; however, since it applies to only a portion of the stock, the actual rate for the entire stock is uncertain. Therefore, until additional data for the entire stock become available, the pinniped default maximum theoretical net productivity rate (RMAX) of 12% will be employed for this harbor seal stock (Wade and Angliss 1997).

The density of harbor seals in the Keyport action area, 0.55/km^2. The density for harbor seals in the DBRC action area is 1.31/km^2. The density of harbor seals year-round in the waters of the QUTR Site was estimated as 0.44/km^2; this density is applicable to nearshore (<50 km) areas only, which represents 52 percent (3,656 km^2/ 7,063 km^2) of the QUTR Site (Appendix A).

Diving Behavior. Harbor seals tend to be benthic feeders but are opportunistic and will forage on seasonally abundant prey species (Stewart and Yochem 1994; Suryan and Harvey 1998). 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. Harbor seal dive depths as deep as 1,463 ft (446 m) have been recorded, although dives greater than 460 ft (140 m) are infrequent.

Acoustics. In-air sounds of harbor seals produce a variety of airborne vocalizations including snorts, snarls, and belching sounds (Bigg 1981). 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 (Kastak and Schusterman 1998; Wolski et al. 2003). Kastak and Schusterman (1996) observed a TTS of 8 dB at 100 Hz, with complete recovery approximately one week following exposure. Kastak et al. (1999) determined that underwater noise of moderate intensity (65 to 75 dB source levels) and duration (20 to 22 min) is sufficient to induce TTS in harbor seals.

Harbor seals are very vigilant and are easily startled. Humans, sea birds and environmental sounds (waves or thunder) can cause seals to flee the haul-out and enter the water. Often seals will quickly return to the haul-out site after the disturbance has passed but in areas of frequent and prolonged disturbances (e.g. kayaks approaching and remaining near a haul-out), the number of seals using that site decreased significantly (Allen et al. 1984).

4.2.18 Sea Otter (*Enhydra lutris kenyoni*)

Stock. Washington

Abundance and Distribution.

Sea otters breed and give birth year-round (Riedman and Estes 1990). The peak pupping period for the Washington population is not defined ; however, breeding and pupping seasons peak about 2-3 months later in Alaska than in California. The Washington population ranges from Neah Bay south to Destruction Island. *Enhydra lutris kenyoni* historically ranged throughout the Aleutian Islands, originally as far north as the Pribilof Islands and in the eastern Pacific Ocean from the Alaskan Peninsula south along the coast to Oregon. This subspecies was extirpated from most of its range during the 1700's and 1800's as the species was exploited for its fur. In 1969 and 1970, a total of 59 sea otters captured at Amchitka Island, Alaska were released in Washington (Jameson et al. 1982). The estimated carrying capacity in Washington has not been determined**.**

The reintroduced population was not surveyed between 1970 and 1977. In 1977, the U.S. Fish and Wildlife Service surveyed the coast and counted only 19 sea otters. The population w as surveyed again in 1978. Between 1981 and 1989 the population was surveyed every other year. Since 1989, data on size and distribution of the Washington sea otter population have been gathered annually using combined aerial and ground counts. Based on the 1994 spring survey (actual count), the minimum population size is 360. Survey conditions during 1 994 w ere less than optima l and the Service believes that the population is probably slightly larger than this count.

Most of the current sea otter range in Washington is within the OCNMS and extends from Destruction Island to Neah Bay (Lance et al. 2004). Since 1999, the largest concentration of sea otters occurs near Destruction Island, northeast of the proposed QUTR action area. Summer surveys in 2004 and 2005 observed 342 and 307 otters, respectively, near Destruction Island (Jameson and Jeffries 2005). In 1999, two individuals were observed 10 mi (16 km) off Grays Harbor south of the core Washington range. In 2000, there was an extension of the winter range with 43 sea otters observed near Kalaloch Rocks (Lance et al. 2004), 1 otter was observed near Split Rock during summer 2000 surveys, and 14 otters were observed near Kalaloch Rocks during summer 2005 surveys. It is possible that sea otters will eventually extend southward into the nearshore area east of the proposed QUTR extension; however, the current range of sea otters is presently restricted to north of Destruction Island (Jameson and Jeffries 2005). Therefore, sea otters are not expected to occur within the QUTR action area (Appendix A).

Diving Behavior.

Sea otters occur in groups of up to 100 individuals or "rafts" and usually consist of females and pups or males. The species inhabits shallow, coastal waters usually associated with rocky substrates supporting kelp forests; however, some use sand bottom habitat where kelp is not present (Riedman and Estes 1990; DeMaster et al. 1996). They seldom range more than 0.6-1.2 mi (1-2 km) from shore and usually forage in depths of 131 ft (40 m) or less primarily on shellfish (sea urchins, abalone, clams, crabs). Most individuals travel between feeding sites and protected resting areas each day and occupy seasonal home ranges of 2-4 mi^2 (5-10 km^2). Female home ranges can encompass over 10 mi (16 km) of coastline while male home ranges are typically between 0.6-1.9 mi (1-3 km) of coastline (Lance et al. 2004). Habitat use varies seasonally with weather and ocean conditions. Females are usually found in more protected waters and males often use more exposed areas. Mating can occur at any time of year, but peaks in the fall; most births occur in the spring/early summer.

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 Cetacean Strandings and Threats

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), 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.

4.3.1 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 U.S. is that "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 animals that strand 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 (Southall, 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 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 (Table 4-3). As published by the NMFS, revised criteria for defining a UME include (71 FR 75234, 2006):

(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 amended the MMPA to establish the Marine Mammal Health and Stranding Response Act (MMHSRA) under authority of the Department of Commerce, National Marine Fisheries Service. The MMHSRP was created out of concern started in the 1980s for marine mammal mortalities, to formalize the response process, and to focus efforts being initiated by numerous local stranding organizations and as a result of public concern.

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 is comprised of smaller organizations manned by professionals and volunteers from nonprofit organizations, aquaria, universities, and state and local governments trained in stranding response, animal health, and diseased investigation. Currently, 141 organizations are authorized by NMFS to respond to marine mammal strandings (National Marine Fisheries Service, 2007o). Through a National Coordinator and six regional coordinators, NMFS authorizes and oversees stranding response activities and provides specialized training for the network.

NMFS Regions and Associated States and Territories

NMFS Northeast Region- ME, NH, MA, RI, CT, NY, NJ, PA, DE, MD, VA

NMFS Southeast Region- NC, SC, GA, FL, AL, MS, LA, TX, PR, VI

NMFS Southwest Region- CA

NMFS Northwest Region- OR, WA

NMFS Alaska Region- AK

NMFS Pacific Islands Region- HI, Guam, American Samoa, Commonwealth of the Northern Mariana Islands (CNMI)

Stranding reporting and response efforts over time have been inconsistent, although effort and data quality within the U.S. have been improving within the last 20 years (NMFS, 2007). Given the historical inconsistency in response and reporting, however, interpretation of long-term trends in marine mammal stranding is difficult (NMFS, 2007). During the past decade (1995 – 2004), approximately 40,000 (about 12,400 are cetaceans) stranded marine mammals have been reported by the regional stranding networks, averaging 3,600 strandings reported per year (Table 4-4; Figure 4-1) (NMFS, 2007). The highest number of strandings were reported between the years 1998 and 2003 (NMFS, 2007). Detailed regional stranding information including most commonly stranded species can be found in Zimmerman (1991), Geraci and Lounsbury (2005), and NMFS (2007).

4.3.2 Unusual Mortality Events (UMEs)

Table 4-1 contains a list of documented UMEs within the U.S.

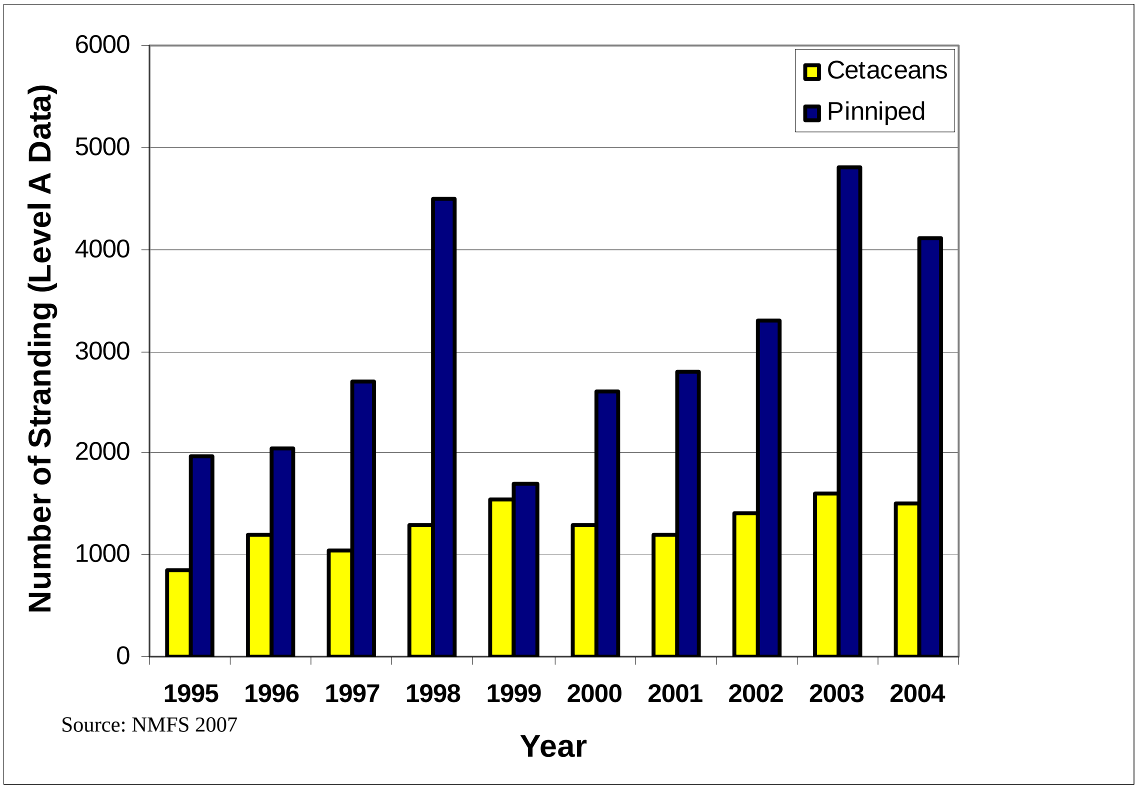
Table 4-1: Documented UMEs within the United States.

Year	Composition	Determination
1993	Harbor seals, Steller sea lions, and California sea lions on the central Washington coast	Human Interaction
1993/1994	Bottlenose dolphins in the Gulf of Mexico	Morbillivirus
1994	Common dolphins in California	Cause not determined
1996	Right whales off Florida/Georgia coast	Evidence of human interactions
1996	Manatees on the west coast of Florida	Brevetoxin
1996	Bottlenose dolphins in Mississippi	Cause not determined
1997	Harbor seals in California	Unknown infectious respiratory disease
1997	Pinnipeds on the Pacific coast	El Niño
1998	California sea lions in central California	Harmful algal bloom; Domoic acid
1999	Harbor porpoises on the East Coast	Determined not to meet criteria for UME because of multiplicity of causes
1999/2000	Bottlenose dolphins in the Panhandle of Florida	Harmful algal bloom is suspected; still under investigation
1999/2000	Gray whales from Alaska to Mexico	Still under investigation
2004	Bottlenose dolphins along the Florida Panhandle	Uncertain, red tide is suspected
2005	Bottlenose dolphins, manatees, sea turtles, and seabirds in west central Florida	Unknown

Source: NMFS 2007c

Table 4-2: Cetacean And Pinniped Stranding Count By NMFS Region 2001-2004.

NMFS Region	# of Cetaceans	# of Pinnipeds
Northeast	1,620	4,050
Southeast	2,830	45
Southwest	12,900	45
Northwest	188	1,430
Alaska	269	348
Pacific Islands	59	10
Four Year Total	17,866	5,928



Source: NMFS 2007

Figure 4-1: United States Annual Cetacean And Pinniped Stranding From 1995-2004.

4.3.3 Threats to Marine Mammals and Potential Causes for Stranding

Reports of marine mammal strandings can be traced back to ancient Greece (Walsh et al., 2001). 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 in and of themselves 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 can be blamed 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 potential stranding causes can include both natural and human influenced (anthropogenic) causes listed below and described in the following sections:

Natural Stranding Causes

Disease

Natural toxins

Weather and climatic influences

Navigation errors

Social cohesion

Predation

Human Influenced (Anthropogenic) Stranding Causes

Fisheries interaction

Vessel strike

Pollution and ingestion

Noise

4.3.4 Natural Stranding Causes

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).

Disease

Like other mammals, marine mammals frequently suffer from a variety of diseases of viral, bacterial, parasites 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 U.S. are carriers of the morbillivirus, yet have grown resistant to its usually lethal effects (Geraci et al. 1999). Since the 1980s, however, virus infections have been strongly associated with marine mammal die-offs (Domingo et al., 1992; Geraci and Lounsbury, 2005). Morbillivirus is the most significant marine mammal virus and suppresses a host’s immune system, increasing risk of secondary infection (Harwood 2002). A bottlenose dolphin UME in 1993 and 1994 was caused by infectious disease. Die-offs ranged from northwestern Florida to Texas, with an increased number of deaths as it spread (NMFS 2007c). A 2004 UME in Florida was also associated with dolphin morbillivirus (NMFS 2004). Influenza A was responsible for the first reported mass mortality in the U.S., occurring along the coast of New England in 1979-1980 (Geraci et al. 1999; Harwood 2002). Canine distemper virus (a type of morbillivirus) 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.

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 although exposure can also occur through inhalation and skin contact (Van Dolah 2005). Figure 4-2 shows U.S. animal mortalities from 1997-2006 resulting from toxins produced during harmful algal blooms.

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 U.S. 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 (Geraci et al. 1999; Van Dolah et al. 2003; Greig et al. 2005; Van Dolah 2005; Brodie et al. 2006; NMFS 2007; Bargu et al. 2008; Goldstein et al. 2008). Other algal toxins associated with marine mammal strandings include saxitoxins and ciguatoxins and are summarized by Van Dolah (2005).

Figure 4-2: Animal Mortalities From Harmful Algal Blooms Within The U.S. From 1997-2006.

Source: Woods Hole Oceanographic Institute (WHO) http://www.whoi.edu/redtide/HABdistribution/HABmap.html

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 decreased prey availability during unusual conditions. This, in turn, results in increased search effort required by marine mammals (Crocker et al. 2006), potential starvation if not successful, and corresponding stranding due directly to starvation or succumbing to disease or predation while in a more weakened, stressed state (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 meridinal 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.

Navigation 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 U.S., 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 topography and patterns may influence long-distance movements (Kirschvink et al. 1986). Walker et al. (1992) examined fin whale swim patterns off the northeastern U.S. continental shelf, and reported that migrating animals aligned with lows in the geometric gradient or 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 whale, 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).

4.3.5 Anthropogenic Stranding Causes and Potential Risks

With the exception of historic whaling in the 19th and early part of the 20th century, over the past few decades there has been an increase in marine mammal mortalities associated with a variety of human activities (Geraci et al. 1999; NMFS 2007). These include fisheries interactions (bycatch and directed catch), pollution (marine debris, toxic compounds), habitat modification (degradation, prey reduction), direct trauma (vessel strikes, gunshots), and noise. Figure 4-3 shows potential worldwide risk to small toothed cetaceans by source.

Fisheries Interaction: By-Catch, Directed Catch, and Entanglement

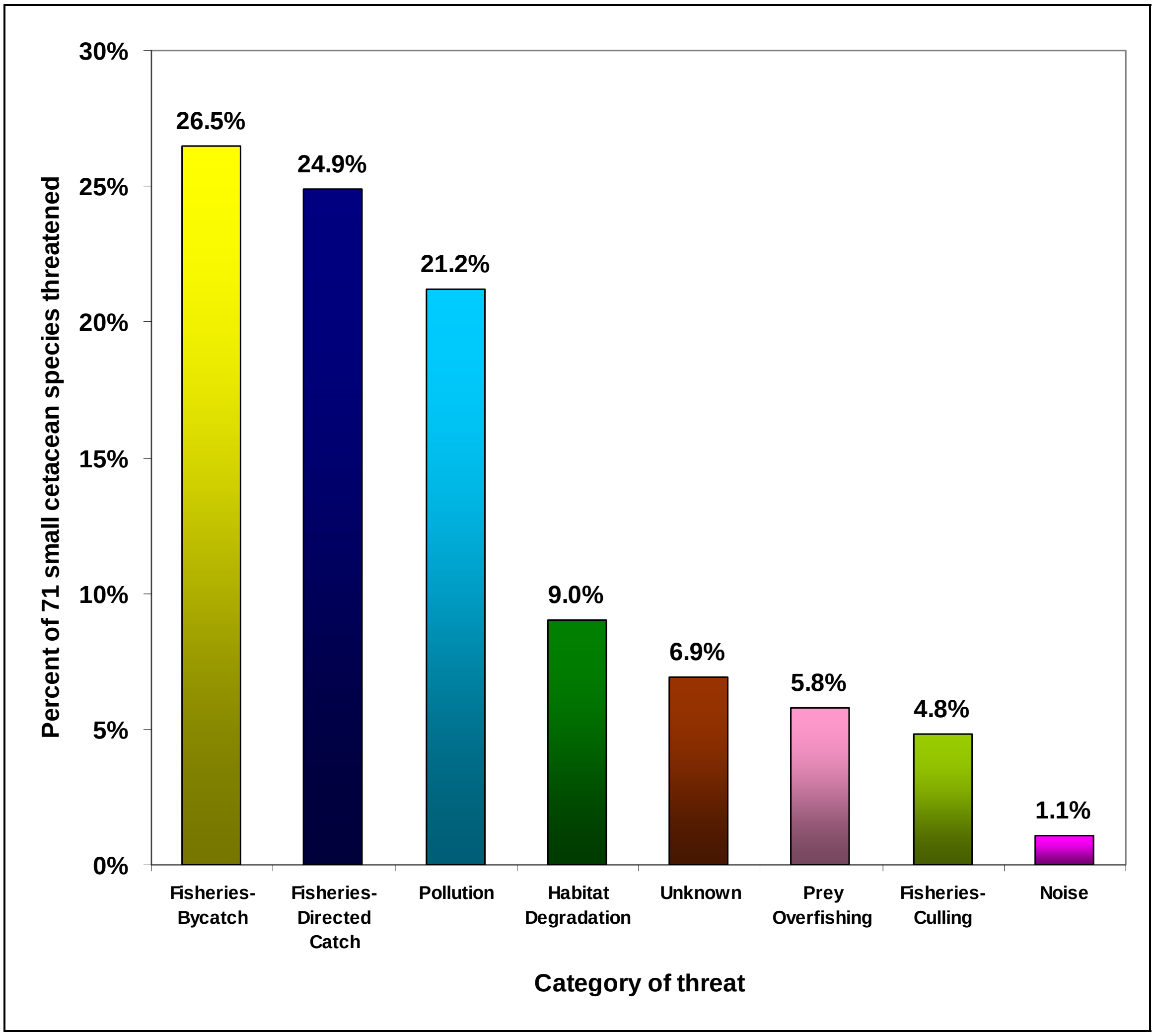
The incidental catch of marine mammals in commercial fisheries is a significant threat to the survival and recovery of many populations of marine mammals (Geraci et al., 1999; Baird 2002; Culik 2002; Carretta et al. 2004; Geraci and Lounsbury 2005; NMFS 2007). Interactions with fisheries and entanglement in discarded or lost gear continue to be a major factor in marine mammal deaths worldwide (Geraci et al. 1999; Nieri et al. 1999; Geraci and Lounsbury 2005; Read et al. 2006; Zeeberg 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- Bycatch is the catching of non-target species within a given fishing operation and can include non-commercially used invertebrates, fish, sea turtles, birds, and marine mammals (NRC 2006). Read et al. (2006) attempted to estimate the magnitude of marine mammal bycatch in U.S. and global fisheries. Data on marine mammal bycatch within the United States was obtained from fisheries observer programs, reports of entangled stranded animals, and fishery logbooks, and was then extrapolated to estimate global bycatch by using the ratio of U.S. fishing vessels to the total number of vessels within the world's fleet (Read et al. 2006). Within U.S. fisheries, between 1990 and 1999 the mean annual bycatch of marine mammals was 6,215 animals, with a standard error of +/- 448 (Read et al. 2006).

Eight-four percent of cetacean bycatch occurred in gill-net fisheries, with dolphins and porpoises constituting most of the cetacean bycatch (Read et al. 2006). Over the decade there was a 40 percent decline in marine mammal bycatch, which was significantly lower from 1995-1999 than it was from 1990-1994 (Read et al. 2006). Read et al. (2006) suggests that this is primarily due to effective conservation measures that were implemented during this time period.

Read et al. (2006) then extrapolated this data for the same time period and calculated an annual estimate of 653,365 of marine mammals globally, with most of the world's bycatch occurring in gill-net fisheries. With global marine mammal bycatch likely to be in the hundreds of thousands every year, bycatch in fisheries will be the single greatest threat to many marine mammal populations around the world (Read et al. 2006).

Entanglement- Entanglement in active fishing gear is a major cause of death or severe injury among the endangered 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 activities may not wash ashore, therefore stranding data may underestimate fishery-related mortalities and serious injuries (NMFS 2005a).



(Source: Culik 2002)

Figure 4-3: Human Threats to World Wide Small Cetacean Populations

From 1993 through 2003, 1,105 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 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), 12 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).

Ship Strike

Vessel 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 2004; 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 although most vessels do travel greater than 15 kts. Jensen and Silber (2004) 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.

U.S. Navy vessel 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 U.S. Navy, probability of vessel strikes is greatly reduced.

Furthermore, actions to avoid close interaction of U.S. 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 watchstanders 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.

Commercial and Private Marine Mammal Viewing

In addition to vessel operations, private and commercial vessels engaged in marine mammal watching also have the potential to impact marine mammals in Southern California. NMFS has promulgated regulations at 50 CFR 224.103, which provide specific prohibitions regarding wildlife viewing activities. In addition, NMFS launched an education and outreach campaign to provide commercial operators and the general public with responsible marine mammal viewing guidelines. In January 2002, NMFS also published an official policy on human interactions with wild marine mammals which states that: “NOAA Fisheries cannot support, condone, approve or authorize activities that involve closely approaching, interacting or attempting to interact with whales, dolphins, porpoises, seals, or sea lions in the wild. This includes attempting to swim, pet, touch or elicit a reaction from the animals.”

Although considered by many to be a non-consumptive use of marine mammals with economic, recreational, educational, and scientific benefits, marine mammal watching is not without potential negative impacts. One concern is that animals become more vulnerable to vessel strikes once they habituate to vessel traffic (Swingle et al. 1993; Wiley et al. 1995). Another concern is that preferred habitats may become abandoned if disturbance levels are too high. A whale’s behavioral response to whale watching vessels depends on the distance of the vessel from the whale, vessel speed, vessel direction, vessel noise, and the number of vessels (Amaral and Carlson 2005; Au and Green 2000; Cockeron 1995; Erbe 2002; Magalhaes et al. 2002; Watkins 1986; Williams et al. 2002). The whale’s responses changed with these different variables and, in some circumstances, the whales did not respond to the vessels, but in other circumstances, whales changed their vocalizations surface time, swimming speed, swimming angle or direction, respiration rates, dive times, feeding behavior, and social interactions. In addition to the information on whale watching, there is also direct evidence of pinniped haul out site (Pacific harbor seals) abandonment because of human disturbance at Strawberry Spit in San Francisco Bay (Allen 1991).

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 (dichlorodiphyenyltrichloroethane), 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 (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). But 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).

U.S. Navy vessel operation between ports and exercise locations has the potential for release of small amounts of pollutant discharges into the water column. U.S. Navy vessels 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.

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).

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Deep Water Ambient Noise

Urick (1983) provided a discussion of the ambient noise spectrum expected in the deep ocean. Shipping, seismic activity, and weather, are the primary causes of deep-water ambient noise. The ambient noise 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 noise 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.

Shallow Water Ambient Noise

In contrast to deep water, ambient noise 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 noise include distant shipping and industrial activities, wind and waves, marine animals (Urick 1983). At any give time and place, the ambient noise is a mixture of all of these noise 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, then when the bottom is absorptive.

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, 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 (U.S. Navy 2001). Ross (1976) has estimated that between 1950 and 1975, shipping had caused a rise in ambient noise levels of 10 dB and predicted this would increase by another 5 dB by the beginning of the 21st century. The National Resource Council (1997) estimated that the background ocean noise 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. Due to the transient nature of sounds from aircraft involved in at-sea operations, such sounds would not likely cause physical effects but have the potential to affect behaviors. 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, swim away from the aircraft track.

Sound emitted from large vessels, particularly in the course of transit, is the principal source of noise 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 noise emitted by a large vessel depending on its travel speed. Military vessels underway or involved in naval operations or exercises, also introduce anthropogenic noise 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. Any masking of environmental sounds or conspecific sounds is expected to be temporary, as noise dissipates with a vessel transit through an area.

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 temporary or permanent threshold shifts (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 permanent threshold shift 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. Whales have variable responses to vessel presence or approaches, ranging from apparent tolerance to diving away from a vessel. It is not 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.

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 kilometers away (Ross 1976 in Polefka 2004). U.S. 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 U.S. 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 U.S. 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.

Stranding Events Associated with Navy Sonar

There are two classes of sonars employed by the U.S. 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 mid-frequency active 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 U.S Navy mid-frequency active 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.

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 [µPa]) 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.

The effects of naval sonars on marine wildlife have not been studied as extensively as have the effects of airguns used in seismic surveys (Nowacek et al. 2007). 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 to have originated from submarine sonar signals (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. Madsen et al. (2006) tagged and monitored eight sperm whales in the Gulf of Mexico exposed to seismic airgun surveys. Sound sources were from approximately 2 to 7 nm (4 to 13 km) away from the whales and based on multipath propagation RLs were as high as 162 dB re 1 uPa with energy content greatest between 0.3 to 3.0 kHz. Sperm whales engaged in foraging dives continued the foraging dives throughout exposures to these seismic pulses. In the Caribbean Sea, sperm whales avoided exposure to mid-frequency submarine sonar pulses, in the range 1000 Hz to 10,000 Hz (IWC 2005). Sperm whales have also moved out of areas after the start of air gun seismic testing (Davis et al. 1995). In contrast, during playback experiments off the Canary Islands, André et al. (1997) reported that foraging sperm whales exposed to a 10 kHz pulsed signal did not exhibit any general avoidance reactions.

The Navy sponsored tests of the effects of low-frequency active (LFA) sonar source, between 100 Hz and 1000 Hz, on blue, fin, and humpback whales. The tests demonstrated that whales exposed to sound levels up to 155 dB did not exhibit significant disturbance reactions, though there was evidence that humpback whales altered their vocalization patterns in reaction to the noise. Given that the source level of the Navy's LFA is reported to be in excess of 215 dB, the possibility exists that animals in the wild may be exposed to sound levels much higher than 155 dB.

Acoustic exposures have been demonstrated to kill marine mammals, result in physical trauma, and injury (Ketten 2005). Animals in or near an intense noise source can die from profound injuries related to shock wave or blast effects. Acoustic exposures can also result in noise induced hearing loss that is a function of the interactions of three factors: sensitivity, intensity, and frequency. Loss of sensitivity is referred to as a threshold shift; the extent and duration of a threshold shift depends on a combination of several acoustic features and is specific to particular species (TTS or PTS, depending on how the frequency, intensity and duration of the exposure combine to produce damage). In addition to direct physiological effects, noise exposures can impair an animal's sensory abilities (masking) or result in behavioral responses such as aversion or attraction.

Acoustic exposures can also result in the death of an animal by impairing its foraging, ability to detect predators or communicate, or by increasing stress, and disrupting important physiological events. Whales have moved away from their feeding and mating grounds (Bryant *et al*. 1984; Morton and Symnods 2002; Weller et al. 2002), moved away from their migration route (Richardson et al. 1995), and have changed their calls due to noise (Miller et al. 2000). Acoustic exposures such as MFA sonar tend to be infrequent and short in duration, and therefore effects are likely indirect and to be short lived. In situations such as the alteration of gray whale migration routes in response to shipping and whale watching boats, those acoustic exposures were chronic over several years (Moore and Clarke 2002). This was also true of the effect of seismic survey airguns (daily for 39 days) on the use of feeding areas by gray whales in the western North Pacific although whales began returning to the feeding area witin one day of the end of the exposure (Weller et al. 2002).

Below are evaluations of the general information available on the variety of ways in which cetaceans and pinnipeds have been reported to respond to sound, generally, and mid-frequency sonar, in particular.

The Navy is very concerned and thoroughly investigates each marine mammal stranding to better understand the events surrounding strandings. 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), environmental conditions (e.g., surface ducting), and multiple sonar ships were compared between the different stranding events.

When a marine mammal swims or floats onto shore and becomes “beached” or stuck in shallow water, it is considered a “stranding” (MMPA section 410 (16 USC section 1421g;NMFS, 2007a). NMFS explains that “a cetacean is considered stranded when it is on the beach, dead or alive, or in need of medical attention while free-swimming in U.S. waters. A pinniped is considered to be stranded either when dead or when in distress on the beach and not displaying normal haul-out behavior” (NMFS 2007b).

Over the past three decades, several “mass stranding” events [strandings involving two or more individuals of the same species (excluding a single cow-calf pair) and at times, individuals from different species] that have occurred over the past two decades have been associated with naval operations, seismic surveys, and other anthropogenic activities that introduce sound into the marine environment (Canary Islands, Greece, Vieques, U.S. Virgin Islands, Madeira Islands, Haro Strait, Washington State, Alaska, Hawaii, North Carolina).

Information was collected on mass stranding events (events in which two or more cetaceans stranded) that have occurred and for which reports are available, from the past 40 years. Any causal agents that have been associated with those stranding events were also identified (Table 4-5). Major range events undergo name changes over the years, however, the equivalent of COMPTUEX and JTFEX have been conducted in southern California since 1934. Training involving sonar has been conducted since World War II and sonar systems have been used since the 1970's (Jane’s 2005).

4.3.6 Stranding Analysis

Over the past two decades, several mass stranding events involving beaked whales have been documented. While beaked whale strandings have been reported since the 1800s (Geraci and Lounsbury 1993; Cox et al. 2006; Podesta et al. 2006), several mass strandings since have been associated with naval operations 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). By the nature of the data, much of the historic information on strandings over the years is anecdotal, which has been condensed in various reports, and some of the data have been altered or possibly misquoted.

The discussion below centers on those worldwide stranding events that may have some association with naval operations, and global strandings that the U.S. Navy feels are either inconclusive or can not be associated with naval operations.

4.3.7 Naval Association

In the following sections, specific stranding events that have been putatively linked to potential sonar operations are discussed. Of note, these events represent a small overall number of animals over an 11 year period (40 animals) and not all worldwide beaked whale strandings can be linked to naval activity (ICES 2005a; 2005b; Podesta et al. 2006). Four of the five events occurred during NATO exercises or events where U.S. Navy presence was limited (Greece, Portugal, Spain). One of the five events involved only U.S. Navy ships (Bahamas).

Beaked whale stranding events potentially associated with potential naval operations.

1996	May	Greece (NATO)
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)

Case Studies of Stranding Events (coincidental with or implicated with naval sonar)

1996 Greece Beaked Whale Mass Stranding (May 12 – 13, 1996)

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, 2000)

Description: Seventeen marine mammals comprised of Cuvier's beaked whales, Blainville's beaked whales (*Mesoplodon densirostris*), minke whale (*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 U.S. Navy use of mid-frequency active 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: 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.

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.

Conclusions: The post-mortem analyses of stranded beaked whales lead 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 mid-frequency sonar use (ICES 2005a, 2005b).

2000 Madeira Island, Portugal Beaked Whale Strandings (May 10 – 14, 2000)

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 2002)

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 known as Neo-Tapon 2002 that involved numerous surface warships and several submarines was being conducted off the coast of the Canary Islands. Tactical mid-frequency active sonar was utilized during the exercises, and strandings began within hours of the onset of the use of mid-frequency sonar (Fernández et al. 2005).

Findings: Eight Cuvier’s beaked whales, one Blainville’s beaked whale, and on 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 mid-frequency 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 lead 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. Tyack et al. (2006) showed that beaked whales often make rapid ascents from deep dives suggesting that it is unlikely that beaked whales would suffer from decompression sickness. Zimmer and Tyack (2007) speculated that if repetitive shallow dives that are used by beaked whales to avoid a predator or a sound source, they could accumulate high levels of nitrogen because they would be above the depth of lung collapse (above about 210 ft) and could lead to decompression sickness. There is no evidence that beaked whales dive in this manner in response to predators or sound sources and other marine mammals such as Antarctic and Galapagos fur seals, and pantropical spotted dolphins make repetitive shallow dives with no apparent decompression sickness (Kooyman and Trillmich, 1986; Kooyman et al., 1984; Baird et al., 2001).

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). Moore and Early (2004) reported that in analysis of sperm whale bones spanning 111 years, gas embolism symptoms were observed indicating that sperm whales may be susceptible to decompression sickness due to natural diving behavior. 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 2006)

Description: The Spanish Cetacean Society reported an atypical mass stranding of four beaked whales that occurred January 26 to 28, 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 U.S. ship under NATO operational command) conducted active sonar training against a Spanish submarine within 50 nm 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):

- Operations 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 the same area over extended periods of time (20 hours) in close proximity.

- Exercises took place in an area surrounded by landmasses, or in an embayment. Operations involving multiple ships employing mid-frequency active 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).

4.3.8 Discussion Of Case Studies From Other Global Strandings

In the following sections, stranding events that have been linked to U.S. Navy activity in popular press are presented. As detailed in the individual case study conclusions, the U.S. Navy believes there is enough evidence available to refute allegations of impacts from mid-frequency sonar, or at least indicate that a substantial degree of uncertainty in time and space that preclude a meaningful scientific conclusion.

2003 Washington State Harbor Porpoise Strandings (May 2 – June 2 2003)

Description: At 1040 hours on May 5, 2003, the USS SHOUP began the use of mid-frequency tactical active 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 U.S. 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 operations (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. It is important to note, however, that these determinations were based only on the evidence from the necropsy so as not to be biased with regard to determinations of the potential presence or absence of acoustic trauma. The result was that other potential causal factors, such as one animal (Specimen 33NWR05005) found tangled in a fishing net, was unknown to the investigators in their determination regarding the likely cause of death.

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). In this regard, 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 5 active 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 mid-frequency sonar. Specifically, in prior events, the stranding of whales occurred over a short period of time (less than 36 hours), stranded individuals were spatially co-located, traumas in stranded animals were consistent between events, and active sonar was known or suspected to be in use. Although mid-frequency active 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 mid-frequency active 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, further supports the conclusion that harbor porpoise strandings were unrelated to the sonar activities of the USS SHOUP.

Additional allegations regarding USS SHOUP use of sonar having caused behavioral effects to Dall's porpoise, orca, and a minke whale also arose in association with this event (see U.S. Department of Navy 2004 for a complete discussion).

Dall's porpoise: Information regarding the observation of Dall's porpoise on 5 May 2003 came from the operator of a whale watch boat at an unspecified location. This operator reported the Dall's porpose were seen "going north" when the SHOUP was estimated by him to be 10 miles away. Potential reasons for the Dall's movement include the pursuit of prey, the presence of harassing resident orca or predatory transient orca, vessel disturbance from one of many whale watch vessels, or multiple other unknowable reasons including the use of sonar by USS SHOUP. In short, there was nothing unusual in the observed behavior of the Dall's porpoise on 5 May 2003 and no way to assess if the otherwise normal behavior was in reaction to the use of sonar by USS SHOUP, any other potential causal factor, or a combination of factors.

Orca: Observer opinions regarding orca J-Pod behaviors on 5 May 2003 were inconsistent, ranging from the orca being "at ease with the sound" or "resting" to their being "annoyed." One witness reported observing "low rates of surface active behavior" on behalf of the orca J-Pod, which is in conflict with that of another observer who reported variable surface activity, tail slapping and spyhopping. Witnesses also expressed the opinion that the behaviors displayed by the orca on 5 May 2003 were "extremely unusual," although those same behaviors are observed and reported regularly on the Orca Network Website, are behaviors listed in general references as being part of the normal repertoire of orca behaviors. Given the contradictory nature of the reports on the observed behavior of the J-Pod orca, it is impossible to determine if any unusual behaviors were present. In short, there is no way to assess if any unusual behaviors were present or if present they were in reaction to vessel disturbance from one of many nearby whale watch vessels, use of sonar by USS SHOUP, any other potential causal factor, or a combination of factors.

Minke whale: A minke whale was reported porpoising in Haro Strait on 5 May 2003, which is a rarely observed behavior. The cause of this behavior is indeterminate given multiple potential causal factors including but not limited to the presence of predatory Transient orca, possible interaction with whale watch boats, other vessels, or SHOUP's use of sonar. The behavior of the minke whale was the only unusual behavior clearly present on 5 May 2003, however, no way to given the existing information if the unusual behavior observed was in reaction to the use of sonar by USS SHOUP, any other potential causal factor, or a combination of factors.

2004 Hawai'i Melon-Headed Whale Mass Stranding (July 3-4 2004)

Description: The majority of the following information is taken from the NMFS report on the stranding event (Southall et al. 2006) but is inclusive of additional and new information not presented in the NMFS report. 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. The whales were reported entering the bay in a "wave as if they were chasing fish" (Braun 2006). At 6:45 a.m. on July 3, 2004, approximately 25 nm north of Hanalei Bay, active sonar was tested briefly prior to the start of an anti-submarine warfare 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. The Navy believes that the abnormal behavior by the whales during this time is likely the result of people and boats in the water with the whales rather than the result of sonar activities taking place 25 or more miles off the coast. 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 mid-frequency active 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.

<u>Findings</u>: 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 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 Navy investigators found that a full moon occurred the evening before the stranding and was coupled with a squid run (Mobley 2007). One of the first observations of the whales entering the bay reported the pod came into the bay in a line "as if chasing fish" (Braun, 2005). 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, possibly 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: It is unlikely that the sound level from the sonar caused the melon-headed whales to enter Hanalei Bay, however, the investigation of this even concluded that there was insufficient evidence to determine causality. 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 the 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 PMRF training range have been used in RIMPAC exercises for more than 20 years, and are used year-round for ASW training using mid frequency active 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 operations 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 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 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 (Mobley et al. 2007). 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 U.S. Naval bases), with strandings in New Zealand (which lacks a U.S. Naval base) and concluded the higher number of strandings in Japan may be related to the presence of the U.S. Navy vessels using mid-frequency 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) in an internal Navy report, looked at the past U.S. 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 U.S. Navy exercises. While the CNA analysis began by investigating the probabilistic nature of any co-occurrences, the strandings and sonar use were not correlated by time. Given there there 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 U.S. Navy vessels did not lead to any of the strandings documented by Brownell et al. (2004).

2004 Alaska Beaked Whale Strandings (7-16 June 2004)

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 these 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 mid-frequency sonar, and no use of explosives in the water. There were no events in the Alaska Shield/Northern Edge exercise that could have caused in 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, 2005)

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 U.S. Navy indicated that from January 12-14 some unit level training with mid-frequency active 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 operations were not unusual for the area or time of year and the vessels were not involved in antisubmarine warfare 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. 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. Severe, sustained (one to four days) winter storms are common for this region.

Over a two-day period (January 16-17), two 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.

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 mid-frequency sonar activity. 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 mid-frequency active 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. 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).

4.3.9 Causal Associations for Stranding Events

As discussed previously, several stranding events have been associated with Navy sonar activities but relatively few of the total stranding events that have been recorded occurred spatially or temporally with

Navy sonar activities. While sonar may be a contributing factor under certain rare conditions, the presence of sonar it is not a necessary condition for stranding events to occur.

A review of past stranding events associated with sonar suggest that the potential factors that may contribute to a stranding event are steep bathymetry changes, narrow channels, multiple sonar ships, surface ducting and the presence of beaked whales that may be more susceptible to sonar exposures. The most important factors appear to be the presence of a narrow channel (e.g., Bahamas and Madeira Island, Portugal) that may prevent animals from avoiding sonar exposure and multiple sonar ships within that channel. These factors are not present during RDT&E activities in the Range Complex.

There have been no mass strandings in the Pacific Northwest attributed to Navy sonar. Given the large military presence and private and commercial vessel traffic in the Keyport, DBRC, and QUTR waters, it is likely that a mass stranding event would be detected. Therefore, it is unlikely that the conditions that may have contributed to past stranding events involving Navy sonar would be present in the Range Complex.

4.3.10 Stranding Section Conclusions

Marine mammal strandings have been a historic and ongoing occurrence attributed to a variety of causes. Over the last fifty years, increased awareness and reporting has lead to more information about species effected and raised concerns about anthropogenic sources of stranding. While there has been some marine mammal mortalities potentially associated with mid-frequency sonar effects to a small number of species (primarily limited numbers of certain species of beaked whales), the significance and actual causative reason for any impacts is still subject to continued investigation.

By comparison and as described previously, potential impacts to all species of cetaceans worldwide from fishery related mortality can be orders of magnitude more significant (100,000s of animals vice 10s of animals) (Culik, 2002; ICES, 2005b; Read et al., 2006). This does not negate the influence of any mortality or additional stressor to small, regionalized sub-populations which may be at greater risk from human related mortalities (fishing, vessel strike, sound) than populations with larger oceanic level distribution or migrations. ICES (2005a) noted, however, that taken in context of marine mammal populations in general, sonar is not major threat, or significant portion of the overall ocean noise budget.

In conclusion, a constructive framework and continued research based on sound scientific principles is needed in order to avoid speculation as to stranding causes, and to further our understanding of potential effects or lack of effects from military mid-frequency sonar (Bradshaw et al., 2005; ICES 2005b; Barlow and Gisiner, 2006; Cox et al. 2006).

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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 MMPA. The authorization requested is for the incidental harassment of marine mammals by behavioral and physiological disruption. However, it is understood that an LOA is applicable for up 5 years, and is appropriate where authorization for serious injury or mortality of marine mammals is requested.

The request is for RDT&E activities conducted within the NAVSEA NUWC Keyport Range Complex. The request is for a 5 year period commencing in September, 2009.

The acoustic modeling approach taken in the NAVSEA NUWC Keyport Range Complex Extension EIS and this LOA request quantifies potential exposures to marine mammals resulting from acoustic activites. Results from this conservative modeling approach are presented with consideration of mitigation measures employed per NUWC Keyport Range Operating Policies and Procedures (Section 11). For example, termination of RDT&E activities when a marine mammal is within the project area, monitoring the project area before initiation of RDT&E activities, and the creation of an exclusion zone around RDT&E activities will all reduce the potential for exposure to mid- and high-frequency acoustic sources.

Modeling results from the NAVSEA NUWC Keyport Range Complex analysis do not predict any marine mammal mortalities. Modeling results for this LOA request do not predict that any marine mammals could be exposed to mid- or high-frequency acoustic sources in excess of PTS threshold indicative of Level A injury. The history of Navy activities in the NAVSEA NUWC Keyport Range Complex and analysis in this document indicate that military readiness activities are not expected to result in any acoustic–induced Level A injury or mortalities to marine mammals.

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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 (Level A or Level B). The Proposed Action is a military readiness activity as defined in the Marine Mammal Protection Act (MMPA), and Section 6.2.1 below defines MMPA Level A and Level B as applicable to military readiness activities. Section 6.2.1 presents how the Level A and 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 Analytical Framework for Assessing Marine Mammal Response to Mid- and High-Frequency Acoustic Sources

When analyzing the results of the mid- and high-frequency acoustic source exposure modeling to provide an estimate of effects, it is important to understand that there are limitations to the ecological data used in the model, and that the model results must be interpreted within the context of a given species' ecology.

As summarized by the National Academies of Science (NAS), the possibility that human-generated sound could harm marine mammals or significantly interfere with their "normal" activities is an issue of increasing concern (National Research Council [NRC] 2005). The NAVSEA NUWC Keyport Range Complex EIS/OEIS, evaluates the potential for the specific Navy acoustic sources used in the Range Complex to result in harassment of marine mammals.

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. Although it is known that sound is important for marine mammal communication, navigation and foraging (NAS 2003; NRC 2005), there are many unknowns in assessing the effects and significance of marine mammals responses to sound exposures.

For this reason, the Navy enlisted the expertise of National Marine Fisheries Service (NMFS) as the cooperating agency. Their input assisted the Navy in developing a conceptual analytical framework for evaluating what sound levels marine mammals might receive as a result of Navy training actions in the Range Complex, whether marine mammals might respond to these exposures, and whether that response might have a mode of action on the biology or ecology of marine mammals such that the response should be considered a potential harassment. From this framework of evaluating the potential for harassment incidents to occur, an assessment of whether acoustic sources might impact populations, stocks or species of marine mammals can be conducted.

The conceptual analytical framework (Figure 6-1) presents an overview of how the mid- and high-frequency acoustic sources used during RDT&E are assessed to evaluate the potential for marine mammals to be exposed to an acoustic source, the potential for that exposure to result in a physiological effect or behavioral response by an animal, and the assessment of whether that response may result in a consequence that constitutes harassment in accordance with MMPA definitions.

The first step in the conceptual model is to estimate the potential for marine mammals to be exposed to a Navy acoustic source. Three questions are answered in this "acoustic modeling" step:

1. **What action will occur?** This requires identification of all acoustic sources that would be used in the exercises and the specific outputs of those sources. This information is provided in Section 3 and 4.
2. **Where and when will the action occur?** The place and season of the action are important to determine which marine mammal species are likely to be present. Species occurrence and density data (Section 3) are used to determine the subset of marine mammals that may be present when an acoustic source is operational.
3. **Predict the underwater acoustic environment that would be encountered.** The acoustic environment here refers to environmental factors that influence the propagation of underwater sound. Acoustic parameters influenced by the place, season, and time are described in this Section.
4. **How many marine mammals are predicted to be exposed to sound from the acoustic sources?** Sound propagation models are used to predict the received exposure level from an acoustic source, and these are coupled with species distribution and density data to estimate the accumulated received energy and maximum sound pressure level that might be received at a level that could be considered as potential harassment. This section also describes the acoustic modeling and presents the number of exposure incidents predicted by the modeling.

The next steps in the analytical framework evaluate whether the sound exposures predicted by the acoustic model might cause a response in a marine mammal, and if that response might be considered harassment of the animal. Harassment includes the concepts of potential injury (Level A Harassment) and behavioral disturbance (Level B harassment). The response assessment portion of the analytical framework examines the following question:

Which potential acoustic exposures might result in harassment of marine mammals?

The predicted acoustic exposures are first considered within the context of the species biology (e.g., can a marine mammal detect the sound, and is that mammal likely to respond to that sound?). Next, if a response is predicted, is that response potentially 'harassment' in accordance with MMPA harassment definitions? For example, if a response to the acoustic exposure has a mode of action that results in a consequence for an individual, such as interruption of feeding, that response or repeated occurrence of that response could be considered "abandonment or significant alteration of natural behavioral patterns," and therefore the exposure(s) would cause Level B harassment.

The following flow chart (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).

Section 6.2 reviews the regulatory framework and premises for the Navy/NMFS marine mammal response analytical framework. Section 6.21 present the analysis by species/stock, presenting relevant information about the species biology and ecology to provide a context for assessing whether modeled exposures might result in incidental harassment. The potential for harassment incidents is then considered 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 impact on species or stocks. Some boxes contained within the flow chart are colored according to how they relate to the definitions of harassment under 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 Level B harassment. Boxes that are shaded from red to yellow have the potential for injury and behavioral disturbance. 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.

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.

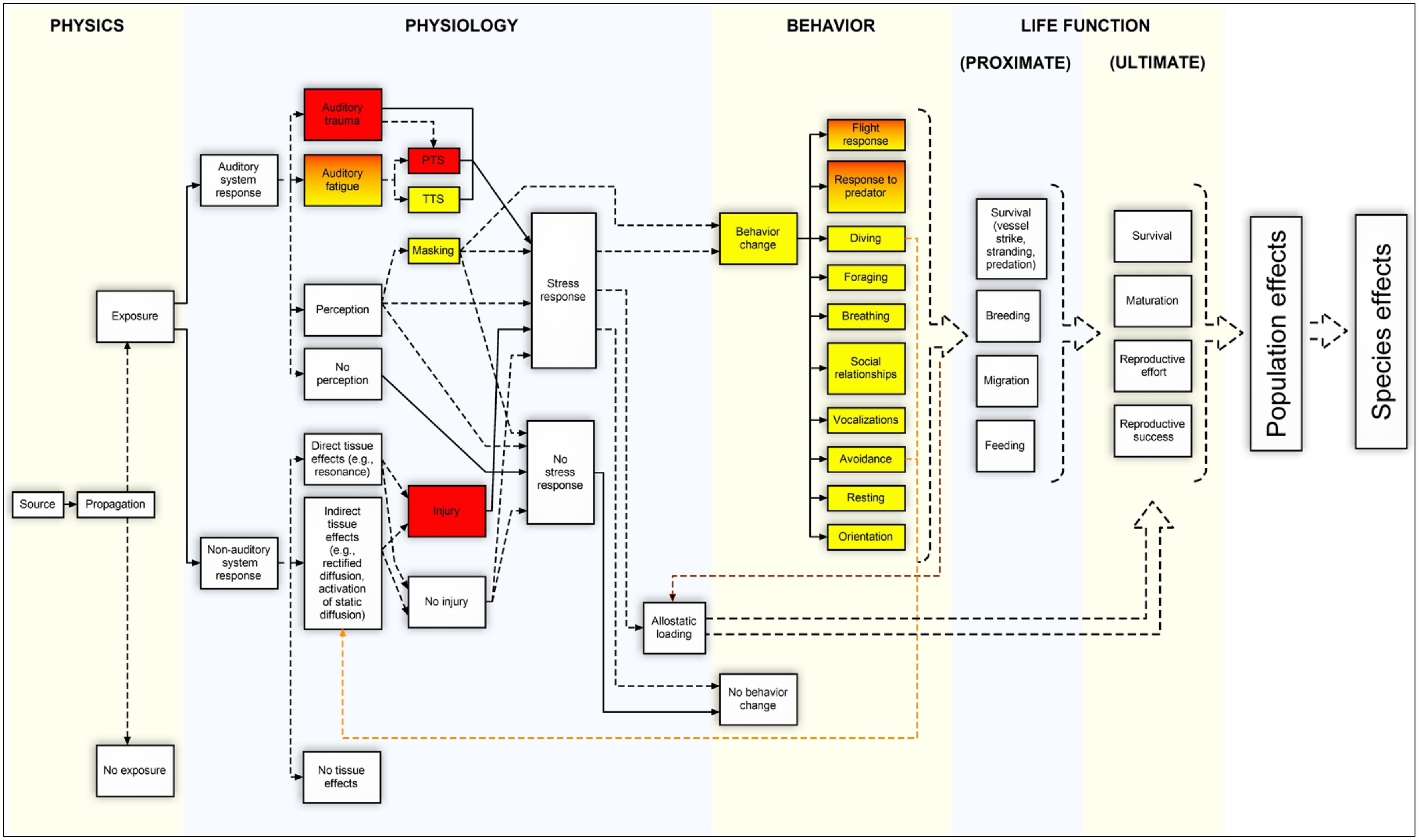


Figure 6-1. Conceptual Model For Assessing The Effects Of Mid-Frequency Sonar Exposures On Marine Mammals.

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.

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 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 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.

Special considerations are given to the potential for avoidance and disrupted diving patterns. Due to past incidents of beaked whale strandings associated with sonar operations, feedback paths are provided between avoidance and diving and indirect tissue effects. This feedback accounts for the hypothesis that variations in diving behavior and/or avoidance responses can possibly result in nitrogen tissue supersaturation and nitrogen off-gassing, possibly to the point of deleterious vascular bubble formation. Although hypothetical in nature, the potential process is currently popular and hotly debated.

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 of breeding 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 RDT&E and/or 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.

6.2 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 the Range Complex RDT&E 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 Level A harassment or Level B harassment as a result of temporary, recoverable physiological effects.

In addition, the approach for estimating potential acoustic effects from RDT&E activities on marine mammals 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 behavioral effects. The risk function is further explained in Section 6.15.

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 Level A and Level B harassment.

The acoustic effects analysis and exposure calculations are based on the following premises:

Harassment that may result from RDT&E activities described in the NAVSEA NUWC Keyport Range Complex EIS/OEIS is unintentional and incidental to those operations.

Behavioral disruption might result in subsequent injury and injury may cause a subsequent behavioral disruption, so Level A and Level B (defined below) harassment categories can overlap and are not necessarily mutually exclusive. However, consistent with prior ruling (NOAA 2001; 2006b), this LOA request assumes that 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 maximum sound pressure level over a 24-hour period as the metric for determining the probability of harassment. 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 Level A harassment being considered 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.

6.3 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 (Level A) and behavioral disruption (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.

6.4 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 and the ESA.

In this LOA 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 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 mid- or high-frequency acoustic sources.

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 mid- or high-frequency acoustic sources.

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.

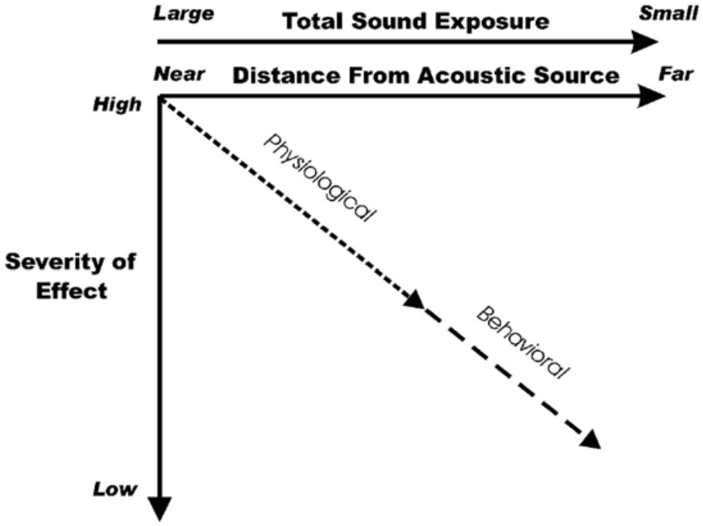


Figure 6-2: Relationship Between Severity of Effects, Source Distance, and Exposure Level.

6.5 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, 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 the NAVSEA NUWC Keyport Range Complex EIS/OEIS 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 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, 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 Level A harassment, which is solely associated with physiological effects, both physiological and behavioral effects may cause 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 Level B harassment. A more general conclusion, that 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 Level B harassment for military readiness activities, which applies to this action. For military readiness activities, 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 Level B harassment. Although modes of action are appropriately considered, as outlined in Figure 3-2, the conservative assumption used here is to consider all hearing impairment as harassment. As a result, the actual incidental harassment of marine mammals associated with this action may be less than predicted via the analytical framework.

6.6 MMPA Exposure Zones

Two acoustic modeling approaches are used to account for both physiological and behavioral effects to marine mammals. This subsection of harassment zones is specific to the modeling of total energy (EL). When using a threshold of accumulated energy (EL) the volumes of ocean in which Level A and Level B harassment 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 Level A or Level B harassment categories. 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.

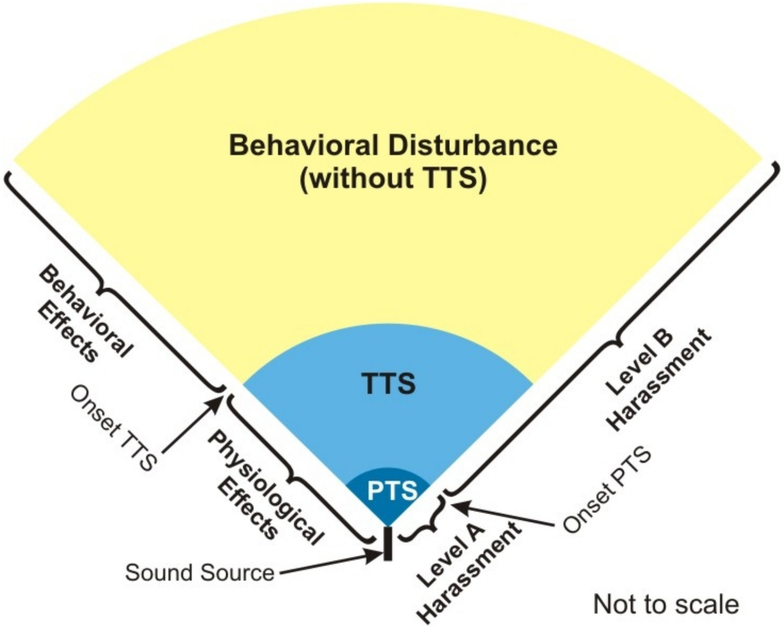


Figure 6-3: Exposure Zones Extending from a Hypothetical, Directional Sound Source.

The Level A 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 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 Level A harassment zone. The threshold used to define the outer limit of the Level A exposure zone is given in Figure 6-3.

The Level B exposure zone begins just beyond the point of slightest injury and extends outward from that point to include all animals that may possibly experience 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 Level B harassment 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 Level B exposure zone for the on-set of certain physiological effects are given in Figure 6-3. Due to the Level B exposure zone developed using accumulated energy, there is a partial overlap with the consideration of potential behavioral disturbance assessed using the risk function, which is a received sound pressure level. This overlap is considered conservative in that it may ‘double-count’ potential exposures, and ensures both physiological and behavioral effects are sufficiently considered.

6.6.1 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 3.19.

6.7 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.

6.8 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 Range Complex, 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 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 Range Complex, 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 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 Range Complex, the potential for TTS is considered as a Level B harassment that is mediated by physiological effects on the auditory system.

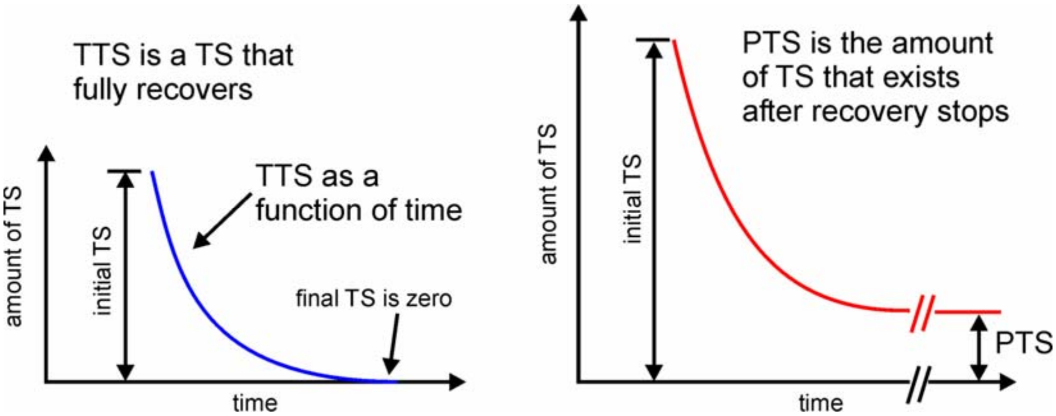


Figure 6-4: Hypothetical Temporary and Permanent Threshold Shifts

6.9 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), 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.

6.9.1 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 µPa)^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.

6.10 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 the NAVSEA NUWC Keyport Range Complex EIS/OEIS.

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).

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 3-5.

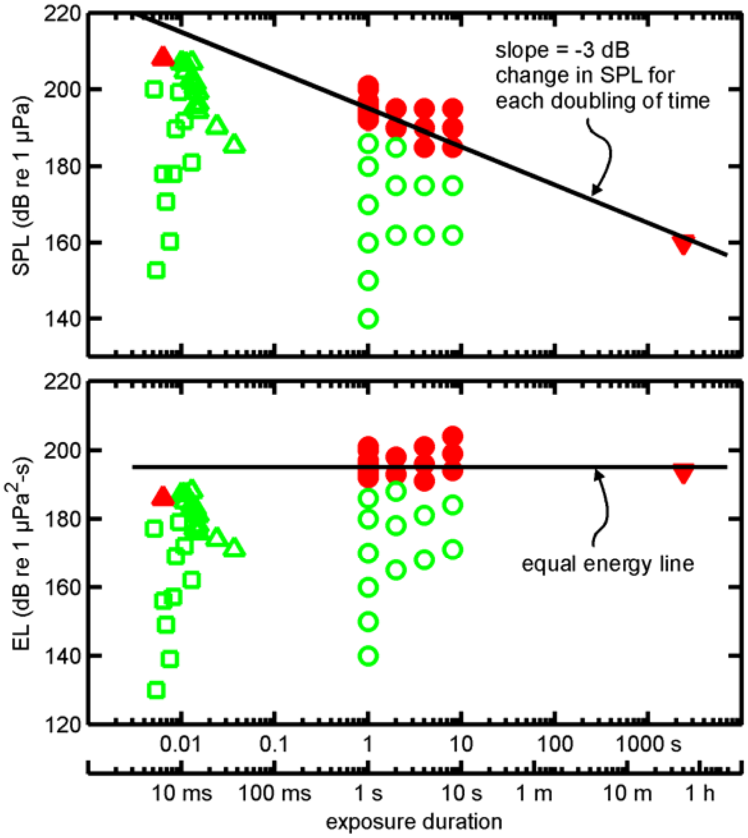


Figure 6-5: Existing TTS Data for Cetaceans.

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.

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 µPa^2-s is the most appropriate predictor for onset-TTS from a single, continuous exposure.

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 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.

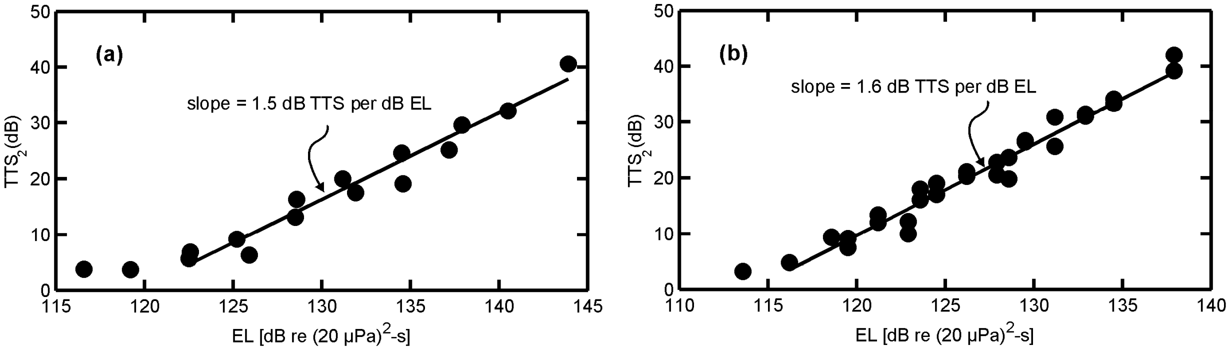


Figure 6-6. Growth of TTS versus the Exposure EL (from Ward et al. [1958, 1959])

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.

For this specified action, sound exposure thresholds for modeling TTS and PTS exposures are as presented in Table 6-1.

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 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 Level B harassment.

The TTS and PTS thresholds for pinnipeds vary with species. A threshold of 206 dB re 1 µPa2-s for TTS and 226 dB re 1 µPa2-s for PTS is used for otariids (Steller sea lion, California 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 6-1. 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 PTS	195 215	Level B Harassment Level A Harassment
Pinnipeds			
Northern Elephant Seal	TTS PTS	204 224	Level B Harassment Level A Harassment
Pacific Harbor Seal	TTS PTS	183 203	Level B Harassment Level A Harassment
Steller Sea Lion	TTS PTS	206 226	Level B Harassment Level A Harassment
California Sea Lion	TTS PTS	206 226	Level B Harassment Level A Harassment
Northern Fur Seal	TTS PTS	206 226	Level B Harassment Level A Harassment

6.11 Derivation of Effect Threshold

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).

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.

6.12 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 + 10log10(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.

6.13 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 µPa2-s as a reference point to derive a TTS threshold in terms of EL. A second explosive effects 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 the MAVSEA NUWC Keyport Range Complex EIS/OEIS. 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). The NAVSEA NUWC Keyport Range Complex EIS/OEIS and 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 mid- or high-frequency acoustic source 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.

6.14 Criteria and Thresholds for Behavioral Effects

Section 6.4 categorized the potential effects of sound into physiological effects and behavioral effects. Criteria and thresholds for physiological effects are discussed in Sections 6.5 through 6.13. 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 mid- or high-frequency acoustic sources to be used in the Range Complex. 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).

6.15 Risk Function Methodology

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 mid- or high-frequency acoustic source 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.

The National Marine Fisheries Service (NMFS) and other commentators recommended the use of an alternate methodology to evaluate when sound exposures might result in behavioral effects without corresponding physiological effects. Therefore, the Navy and NMFS have developed the Risk-Function approach to estimate potential behavioral effects from mid-frequency active sonar. The behavioral response exposures presented in this chapter were estimated using the risk function methodology described below.

6.15.1 Applying the Risk Function Methodology

The methodology described below is based on surface ship acoustic sources. The NAVSEA NUWC Keyport Range does not utilize these sources in RDT&E activities. It should be noted though, that the sources methodology described below is utilized for the modeling of potential exposures to mid- and high-frequency

To assess the potential effects on marine mammals associated with mid- or high-frequency acoustic sources used during RDT&E activities, the Navy together with NMFS, as a first step, investigated a series of mathematical models and methodologies that estimate the number of times individuals of the different species of marine mammals might be exposed to MFA sonar at different received levels. The Navy effects analyses assumed that the potential consequences of exposure to MFA sonar on individual animals would be a function of the received sound pressure level (decibels re 1 micropascal [dB re 1 µPa]). These analyses assume that MFA sonar poses no risk, that is, does not constitute harassment to marine mammals if they are exposed to sound pressure levels from the MFA sonar below a certain basement value.

The second step of the assessment procedure requires the Navy and NMFS to identify how marine mammals are likely to respond when they are exposed to mid- or high-frequency acoustic sources. Marine mammals can experience a variety of responses to sound including sensory impairment (permanent and temporary threshold shifts and acoustic masking), physiological responses (particular stress responses), behavioral responses, social responses that might result in reducing the fitness of individual marine mammals and social responses that would not result in reducing the fitness of individual marine mammals.

Previously, the Navy and NMFS have used acoustic thresholds to identify the number of marine mammals that might experience hearing losses (temporary or permanent) or behavioral harassment upon being exposed to MFA sonar (see Figure 3.9.3, left panel). These acoustic thresholds have been represented by either sound exposure level (related to sound energy, abbreviated as SEL), sound pressure level (SPL), or other metrics such as peak pressure level and acoustic impulse (not considered for sonar in this LOA). The general approach has been to apply these threshold functions so that a marine mammal is counted as behaviorally harassed or experiencing hearing loss when exposed to received sound levels above a certain threshold and not counted as behaviorally harassed or experiencing hearing loss when exposed to received levels below that threshold. For example, previous Navy EISs, environmental assessments, MMPA take authorization requests, and the MMPA incidental harassment authorization (IHA) for the Navy’s 2006 Rim-of-the Pacific (RIMPAC) Major Exercise (FR 71.38710-38712, 2006) used 173 dB re 1 μPa^2-second (sec) as the energy threshold level (i.e., SEL) for Level B behavioral harassment for cetaceans. If the transmitted accumulated energy received by a whale was above 195 dB re 1 μPa^2-sec, then the animal was considered to have experienced a temporary loss in the sensitivity of its hearing. The left panel in Figure 6-7 illustrates a typical step-function or threshold that might also relate a sonar exposure to the probability of a response. As this figure illustrates, past Navy/NMFS acoustic thresholds assumed that every marine mammal above a particular received level (for example, to the right of the red vertical line in the figure) would exhibit identical responses to a sonar exposure. This assumed that the responses of marine mammals would not be affected by differences in acoustic conditions; differences between species and populations: differences in gender, age, reproductive status, or social behavior; or the prior experience of the individuals.

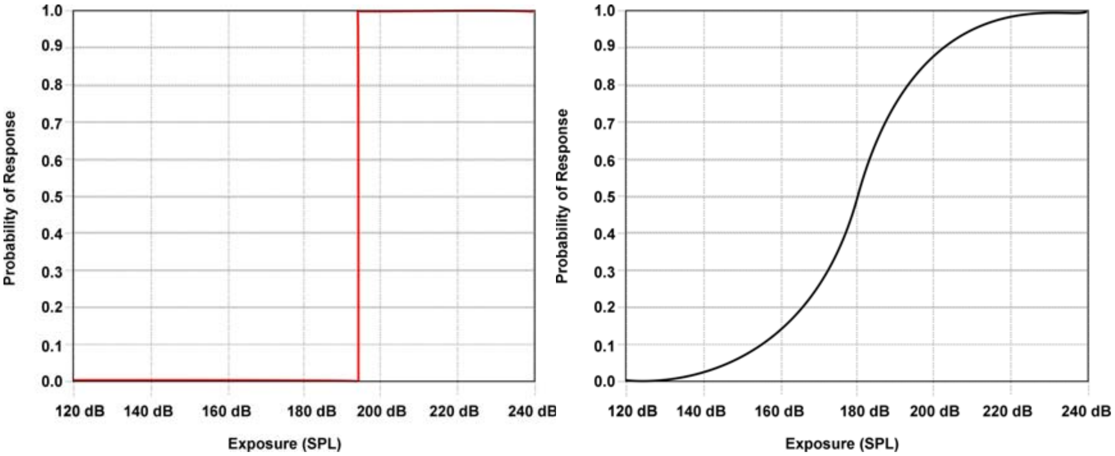


Figure 6-7. Typical Step Function (Left) And Typical Risk Continuum-Function (Right)

In this figure, for the typical step function (left panel) the probability of a response is depicted on the y-axis and received exposure on the x-axis. The right panel illustrates a typical risk continuum-function using the same axes. SPL is "Sound Pressure Level" in decibels referenced to 1 μPa root mean square (rms).

Both the Navy and NMFS agree that the studies of marine mammals in the wild and in experimental settings do not support these assumptions—different species of marine mammals and different individuals of the same species respond differently to sonar exposure. Additionally, there are specific geographic/bathymetric conditions that dictate the response of marine mammals to sonar that suggest that different populations may respond differently to sonar exposure. Further, studies of animal physiology suggest that gender, age, reproductive status, and social behavior, among other variables, probably affect how marine mammals respond to sonar exposures (Wartzok et al. 2003; Southall et al. 2007).

Over the past several years, the Navy and NMFS have worked on developing an MFA sonar acoustic risk function to replace the acoustic thresholds used in the past to estimate the probability of marine mammals being behaviorally harassed by received levels of MFA sonar. The Navy and NMFS will continue to use acoustic thresholds to estimate temporary or permanent threshold shifts using SEL as the appropriate metric. Unlike acoustic thresholds, acoustic risk continuum functions (which are also called "exposure-response functions," "risk-response functions," or "stress-response functions" in other risk assessment contexts) assume that the probability of a response depends first on the "dose" (in this case, the received level of sound) and that the probability of a response increases as the "dose" increases. It is important to note that the probabilities associated with acoustic risk functions do not represent an individual's probability of responding. Rather, the probabilities identify the proportion of an exposed population that is likely to respond to an exposure.

The right panel in Figure 6-7 illustrates a typical acoustic risk function that might relate an exposure, as received SPL in dB re 1 µPa, to the probability of a response. As the exposure receive level increases in this figure, the probability of a response increases as well but the relationship between an exposure and a response is "linear" only in the center of the curve (that is, unit increases in exposure would produce unit increases in the probability of a response only in the center of a risk function curve). In the "tails" of an acoustic risk function curve, unit increases in exposure produce smaller increases in the probability of a response. Based on observations of various animals, including humans, the relationship represented by an acoustic risk function is a more robust predictor of the probable behavioral responses of marine mammals to sonar and other acoustic sources.

The Navy and NMFS have previously used the acoustic risk function to estimate the probable responses of marine mammals to acoustic exposures for other training and research programs. Examples of previous application include the Navy Final EISs on the SURTASS LFA sonar (DoN 2001); the North Pacific Acoustic Laboratory experiments conducted off the Island of Kauai (Office of Naval Research, 2001), and the Supplemental EIS for SURTASS LFA sonar (DoN 2007a).

The Navy and NMFS used two metrics to estimate the number of marine mammals that could be subject to Level B harassment (behavioral harassment and TTS) as defined by the MMPA, during training exercises. The agencies used acoustic risk functions with the metric of received SPL (dB re 1 µPa) to estimate the number of marine mammals that might be at risk for MMPA Level B behavioral harassment as a result of being exposed to MFA sonar. The agencies will continue to use acoustic thresholds ("step-functions") with the metric of SEL (dB re 1 µPa2-s) to estimate the number of marine mammals that might be "taken" through sensory impairment (i.e., Level A – PTS and Level B – TTS) as a result of being exposed to MFA sonar.

Although the Navy has not used acoustic risk functions in previous MFA sonar assessments of the potential effects of MFA sonar on marine mammals, risk functions are not new concepts for risk assessments. Common elements are contained in the process used for developing criteria for air, water, radiation, and ambient noise and for assessing the effects of sources of air, water, and noise pollution. The Environmental Protection Agency (EPA) uses dose-functions to develop water quality criteria and to regulate pesticide applications (U.S. EPA 1998); the Nuclear Regulatory Commission (NRC) uses dose-functions to estimate the consequences of radiation exposures (see NRC 1997 and 10 Code of Federal Regulations [C.F.R] § 20.1201); the Centers for Disease Control and Prevention (CDCP) and the Food and Drug Administration (FDA) use dose-functions as part of their assessment methods (for example, see CDCP 2003, U.S. FDA 2001); and the Occupational Safety and Health Administration (OSHA) uses dose-functions to assess the potential effects of noise and chemicals in occupational environments on the health of people working in those environments (for examples, see FR 61:56746-56856, 1996; FR 71:10099-10385, 2006).

6.15.2 Risk Function Adapted from Feller (1968)

The particular acoustic risk function developed by the Navy and NMFS 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 (DoN 2001), and relied on in the Supplemental SURTASS LFA Sonar EIS (DoN 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, and pinnipeds.

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).

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

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) (explained in 3.1.5.3).

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.

6.15.3 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, designed as acoustic experiments rather than behavioral 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 μPa rms, and beluga whales did so at received levels of 180 to 196 dB and above.

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.

<u>Data from Studies of Baleen (Mysticetes) Whale Responses</u>: The only mysticete data available resulted from a field experiments in which baleen whales (mysticetes) were exposed to a range frequency sound sources from 500 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 operations 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 operations 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.

NMFS (2005), DoN (2004), and 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.

6.15.4 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):
- 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
- 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.

6.15.5 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 6.15.2. The risk continuum function approximates the risk-response function in a manner analogous to pharmacological risk assessment (DoN 2001, Appendix A). In this case, the risk function is combined with the distribution of sound exposure levels to estimate aggregate impact on an exposed population.

6.15.6 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 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 scientists, 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 sonar has a negligible impact on the subsequent calculations, because the risk function does not attain appreciable values at received levels that low.

6.15.7 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.

6.15.8 Risk Transition—The A Parameter

The A parameter controls how rapidly risk transitions from low to high values with increasing receive level (Figures 6-8 and 6-9) . 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, and pinnipeds (NMFS 2008). This is the same value of A that was used for the SURTASS LFA sonar analysis. As stated in the SURTASS LFA Sonar Final OEIS/EIS (DoN 2001), 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). The choice of a more gradual slope than the empirical data was consistent with other decisions for the SURTASS LFA Sonar Final OEIS/EIS to make conservative assumptions when extrapolating from other data sets (see Subchapter 1.43 and Appendix D of the SURTASS LFA Sonar OEIS/EIS [NMFS 2008]).

Based on NMFS' direction, the Navy will use a value of A=8 for mysticetes to allow for greater consideration of potential harassment at the lower received levels based on Nowacek et al., 2004 (NMFS 2008). In addition, while the TTS and PTS thresholds remain the same for harbor porpoise, the risk function is defined for behavioral exposure as a step function (see Figure 6-7) at 120 dB SPL.

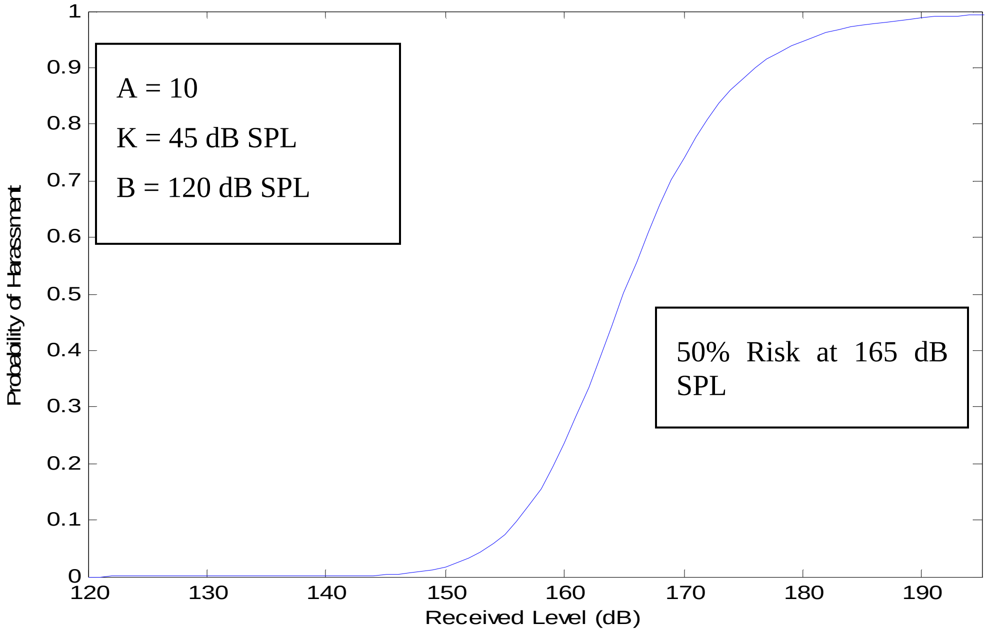


Figure 6-8. Risk Function Curve for Odontocetes (Toothed Whales) and Pinnipeds

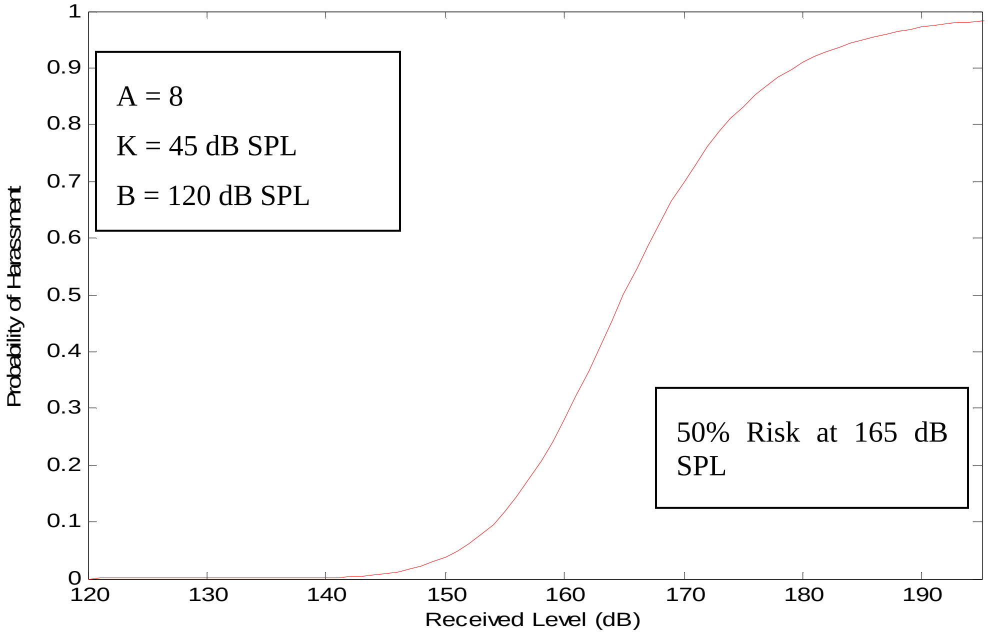


Figure 6-9. Risk Function Curve for Mysticetes (Baleen Whales)

6.15.9 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 testing and training 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 moving away can affect the way an animal responds to a sound (Wartzok et al. 2003). 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. For example, in the case of sonar usage in the Range Complex, a portion of the animals that are likely to be "taken" through behavioral harassment are expected to be exposed at relatively low received levels (120-140 dB SPL) where the significance of those responses would be reduced because of the distance (25-65 nm) from a sound source. Alternatively, only a relatively very small portion (<5%) of the animals that are expected to be "taken" through behavioral harassment are expected to occur when animals are exposed to higher received levels, such as the onset of TTS (195 dB re 1 μPa^2-s) or higher. Since the modeling does not take into account the reduction of effects resulting from the Navy's standard mitigation, approximately 25% of all exposures are modeled as having occurred within the 1,000 yard mitigation safety zone where procedures are in place to reduce the received level of animals within this zone. 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.

6.15.10 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 mid- or high-frequency acoustic sources near land are not reduced to account for the land mass where marine mammals would not occur.
- Acoustic footprints for mid- or high-frequency acoustic sources were added independently and, therefore, did not account for overlap they would have with other systems used during the same RDT&E 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 source levels when marine mammals are present.
- Marine mammal densities were averaged across specific RDT&E 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.

Table 6-2 provides a summary of the modeling protocols used in the analysis for this LOA.

Table 6-2. Navy Protocols Providing for Modeling Quantification of Marine Mammal Exposures

Historical Data	Sonar Positional Reporting System (SPORTS)	Annual active sonar usage data will be obtained from the SPORTS database to determine the number of active sonar hours and the geographic location of those hours for modeling purposes.
Acoustic Parameters	AN/SQS-53 and AN/SQS-56	Model the AN/SQS-53 and the AN/SQS-56 active sonar sources separately to account for the differences in source level, frequency, and exposure effects.
	Submarine Sonar	Submarine active sonar use will be included in effects analysis calculations using the SPORTS database.
Post Modeling Analysis	Land Shadow	For sound sources within the acoustic footprint of land, subtract the land area from the marine mammal exposure calculation.
	Multiple Ships	Correction factors will be used to address overestimates of exposures to marine mammals resulting from multiple counting when there are more than one ship operating in the same vicinity.
	Multiple Exposures	The following refresh rates for the Range Complex training events will be included to account for multiple exposures: Unit-level Training, Coordinated Events, and Maintenance – 4 hours Major Exercises / Major Range Events– 12 hours Sustainment Training Exercises – 12 hours.

6.16 Other Effects Considered

6.16.1 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). 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 (ETP) 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- or high-frequency acoustic sources 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.

6.16.2 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 (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.

6.16.3 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). 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. Beaked whales are, however, assessed differently from other species to account for factors that may have contributed to prior beaked whale strandings as set out in the previous section.

6.16.4 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 (DOC 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.

6.16.5 Likelihood of Prolonged Exposure

The proposed RDT&E activities within the Range Complex would not result in prolonged exposure because the vessels are constantly moving, and the flow of the activity in the Range Complex when RDT&E activities 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.

6.16.6 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 NAVSEA NUWC Keyport Range Complex RDT&E 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 mid- and high-frequency acoustic sources. These 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 mid- and high-frequency acoustic sources transmit within a narrow band of frequencies (typically less than one-third octave).

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

6.16.7 Long-Term Effects

Navy activities are conducted in the same general areas throughout the Range Complex, 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 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 Range Complex 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.

6.16.8 Application of Exposure Thresholds to Other Species

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.

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." (DoC 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 RDT&E activities. Mitigation measures based on the Bahamas investigation are presented in Chapter 11.1. The confluence of these factors do not occur in the NAVSEA NUWC Keyport Range Complex areas. 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 NAVSEA NUWC Keyport Range Complex associated with the 60-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) 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 where sonar use has historically taken place, it is likely that beaked whales have been occasionally exposed to sonar during the last 60 years of sonar use off the coast of Washington and yet there is no indication of any adverse impact on beaked whales from exposure to mid- and high-frequency acoustic sources in Washington waters. Therefore, the continued use of mid- and high-frequency acoustic sources in the NAVSEA NUWC Keyport Range Complex is not likely to result in effects to beaked whales.

Since the exact causes of the stranding events are unknown, separate, meaningful impact thresholds cannot be derived specifically for beaked whales. The Navy, in consideration of the repetitive use of mid- and high-frequency acoustic sources proposed for NAVSEA NUWC Keyport Range Complex activities is taking a conservative approach and has extended the Risk Function cut off to 141 dB.

Pinnipeds

The majority of pinniped sounds are in the sonic range (20 Hz to 20 kHz) (Ketten 1998; Wartzok and Ketten, 1999). In general, phocids are far more vocal underwater than are otariids. Phocid calls are commonly between 100 Hz and 15 kHz, with peak spectra less than 5 kHz, but can range as high as 40 kHz (Ketten, 1998; Wartzok and Ketten, 1999). There is no evidence that pinnipeds echolocate (Schusterman et al., 2000). Pinniped hearing falls within the range of MFA sonar but to date there is little information on the effect of sonar on pinnipeds. Most of the acoustic behavior of pinnipeds takes place onshore at rookeries or just offshore for species that may hold territories in the water.

Pinnipeds are common in waters where sonar use has historically taken place, it is likely that pinnipeds have been occasionally exposed to sonar during the last 40 years of sonar use in Southern California and yet there is no indication of any adverse impact from exposure to sonar in Californian waters. Therefore, the continued use of sonar in the NAVSEA NUWC Keyport Range Complex is not likely to result in effects to pinnipeds.

6.16.9 Marine Mammal Mitigation Measures Related to Acoustic Effects

In lieu of mitigation measures used for training operations, all RDT&E range activities within the NAVSEA NUWC Keyport Range Complex are conducted in compliance with the Range Operating Policies and Procedures Manual (*ROP)* (NUWC Keyport 2006) and the *Range Users Guide* (NUWC Keyport 2004a) to protect the health and safety of the public and Navy personnel, as well as the marine environment. These documents address issues such as safety, development of approved run plans, responsibilities of range operation personnel, deficiency reporting, all facets of range activities, and establishing ‘exclusion zones’ to ensure that there are no marine mammals within a certain area prior to the commencement of each in-water exercise. None of the tests involve explosive warheads, and every effort is made to ensure public safety.

NUWC Keyport operates in cooperation with local maritime activities, Tribal fishing, commercial and recreational fisheries, and public recreation. Rarely do NAVSEA NUWC Keyport Range Complex activities require complete restricted access from operating areas, and active acoustic activities are postponed if whales, dolphins, or porpoises (cetaceans) are observed in the range. Ranging is also postponed when seals or sea lions (pinnipeds) are within 100 yards (91 m) of the intended track. All operators are trained by NOAA personnel in marine mammal identification. Moreover, passive listening devices on range can detect vocalizing marine mammals not seen on the surface. Procedures for real-time reporting of marine mammals are in place and are orchestrated by the Range Officer at all range sites. Both the Keyport Range Site and the DBRC Site have shore-to-shore surveillance capability because of the proximity of land on both sides. This provides the Navy a unique opportunity to implement marine mammal surveillance procedures. This policy is implemented for current RDT&E activities and would continue to be implemented as appropriate at all range sites as part of any of the proposed alternatives, including the No-Action Alternative.

Range Site Public Safety Procedures

The Navy implements a variety of procedures to ensure the safety of the general public, marine mammals, fish, and the human environment during testing activities at all range sites. NUWC Keyport conducts a thorough environmental and safety review for all test systems before the tests are conducted on any of the range sites. Prior to going into the water, most systems go through land-based shop testing and many have been tested in smaller fresh water areas or tanks. Shop testing can be quite rigorous and may include, but not be limited to, pressure integrity, leak resistance, and guidance and control logic. After an initial review, modifications can be made, as needed, to minimize the amount of expended material and the potential impacts to public safety and the natural environment. Other procedures to ensure public safety include communicating test activities at the DBRC Site to Tribes, regulators, and the public.

Navy personnel on guard boats may be used to communicate with non-military vessels unaware of the test restrictions or to provide other information (e.g., having non-military vessels shut off their engines for a short time to eliminate acoustical interference during noise-sensitive testing or, less commonly, having them remain outside the testing area for a period of time until the activity is completed). Other communication procedures for advising non-military vessels of test restrictions are described below.

For the majority of testing activities at the Keyport Range, DBRC, and QUTR sites, the procedures outlined above are sufficient to notify the public of activities and ensure public safety. Halting marine traffic is typically not required as a safety measure, as test units run at sufficient depth and have no live warheads that would present a risk to surface vessels. In cases where certain testing and equipment retrieval activities involve navigational hazards, the Navy coordinates with the U.S. Coast Guard to issue a Notice to Mariners (NOTMAR). Marine radio channels 12 or 16 are monitored by all range craft and range control during range activities in accordance with safety afloat regulations. This also helps to minimize conflicts with Tribal, commercial, and private vessels.

The DBRC instrumented site is the only range site where unique fixed warning lights are used. There are no warning lights used at the Keyport Range or QUTR sites. The Navy maintains yellow, white, and red warning lights at Sylopash, Pulali, Whitney, and Zelatched points, and the southeast edge of Bolton Peninsula, all within sight of the Dabob Bay MOA. The lights warn non-military craft of the status of Navy activities within the MOA. The descriptions of the lights are posted at local boat ramps and marinas on NUWC Keyport Form 5720/3 (Rev 6-93), and are clearly indicated on standard NOAA charts (e.g., NOAA Nautical Chart No. 18458). Yellow or alternating white and yellow lights indicate to non-military vessels that: 1) they should proceed with caution; 2) range activities are in progress, but no noise-sensitive acoustic measurement tests are in progress; or 3) vessels should be prepared to shut down engines when lights change to red. Red or alternating white and red lights indicate: 1) range activities involving critical measurements are in progress; 2) engines should be stopped until red beacons have been shut off, indicating the test is completed; and 3) advice of Navy personnel on guard boats should be followed when in or near the range site. Typically, boat passage is permitted between tests when the yellow beacons are operating.

After-Action Reporting

Following the completion of each test, NUWC Keyport personnel evaluate the performance of the test and compile information into a weekly report for the NUWC Keyport Commanding Officer. The report summarizes items relating to equipment, software, procedures, safety, and the environment (e.g., marine mammal sightings).

6.17 Modeling Acoustic Effects

The methodology for analyzing potential impacts from mid- and high-frequency acoustic sources is presented in this section, which defines the model process in detail, describes how the impact threshold derived from Navy-NMFS consultations are derived, and discusses relative potential impact based on species biology.

The Navy acoustic exposure model process uses a number of inter-related software tools to assess potential exposure of marine mammals to Navy generated underwater sound including sonar and explosions. For sonar, these tools estimate potential impact volumes and areas over a range of thresholds for sonar specific operating modes. Results are based upon extensive pre-computations over the range of acoustic environments that might be encountered in the operating area.

The process includes four steps used to calculate potential exposures:

- Identify unique acoustic environments that encompass the operating area. Parameters include depth and seafloor geography, bottom characteristics and sediment type, wind and surface roughness, sound velocity profile, surface duct, sound channel, and convergence zones.
- Compute transmission loss (TL) data appropriate for each sensor type in each of these acoustic environments. Propagation can be complex depending on a number of environmental parameters listed in step one, as well as sonar operating parameters such as directivity, source level, ping rate, and ping length. The Navy standard CASS-GRAB acoustic propagation model is used to resolve these complexities for underwater propagation prediction.
- Use that TL to estimate the total sound energy received at each point in the acoustic environment.
- Apply this energy to predicted animal density for that area to estimate potential acoustic exposure, with animals distributed in 3-D based on best available science on animal dive profiles.
- Modeling of the effects of mid- and high-frequency acoustic sources was conducted using methods described in the following sections.

The primary potential impact to marine mammals from underwater acoustics is Level B harassment from noise. Analysis of noise impacts to cetaceans is based on criteria and thresholds initially presented in U.S. Navy Environmental Impact Statements for ship shock trials of the Seawolf submarine and the Winston Churchill (DDG 81), and subsequently adopted by NMFS.

A certain proportion of marine mammals are expected to experience behavioral disturbance at different received sound pressure levels and are counted as Level B harassment exposures. The details of this “sub-TTS” theory and calculation are described in the later in this section. Table 6-5 lists the physiological thresholds for mid- and high-frequency acoustic sources derived from NMFS consultations and rulemaking.

The sound sources will be located in an area that is inhabited by species listed as threatened or endangered under the Endangered Species Act (ESA, 16 USC §§ 1531-1543). If a federal agency determines that its proposed action “may affect” a listed species, it is required to consult, either formally or informally, with the appropriate regulator. The Navy will initiate formal consultation under the ESA by submitting a Biological Assessment to NMFS, detailing the proposed action’s potential effects on listed species and any designated critical habitat.

6.17.1 Acoustic Sources

For modeling purposes, acoustic source parameters were based on records from previous RDT&E activities, to reflect the underwater sound use expected to occur during activities in the NAVSEA NUWC Keyport Range Complex. The actual acoustic source parameters in many cases are classified, however, modeling used to calculate exposures to marine mammals employed actual and preferred parameters which have in the past been used during RDT&E activities in the NAVSEA NUWC Keyport Range Complex.

Every use of underwater acoustic energy 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 acoustic source is operated (i.e., source level, depth, frequency, pulse length, directivity, platform speed, repetition rate). A wide variety of systems/equipment that utilize narrowband acoustic sources are employed at the NAVSEA NUWC Keyport Range Complex.

Eight have been selected as representative of the types of operating in this range and are described in Table 6-3. Take estimates for these sources are calculated and reported on a per-run basis.

Table 6-3: Mid- and High-frequency Acoustic Sources Employed in the NAVSEA NUWC Keyport Range Complex

Source Designation	Acoustic Source Description	Frequency Class	Takes Reported
S1	Sub-bottom profiler	Mid-frequency	Per 4-hour run
S2	UUV source	High frequency	Per 2-hour run
S3	REMUS Modem	Mid-frequency	Per 2-hour run
S4	REMUS-SAS-HF	High frequency	Per 2-hour run
S5	Range Target	Mid-frequency	Per 20-minute run
S6	Test Vehicle 1	High-frequency	Per 10-minute-run
S7	Test Vehicle 2	High-frequency	Per 10-minute-run
S8	Test Vehicle 3	High-frequency	Per 10-minute-run

The acoustic modeling that is necessary to support the take estimates for each of these sources relies upon a generalized description of the manner of the operating modes. This description includes the following:

- "Effective" energy source level – The total energy across the band of the source, scaled by the pulse length (10 log10 [pulse length]).
- Source depth – Depth of the source in meters. Each source was modeled in the middle of the water column.
- Nominal frequency – Typically the center band of the source emission. These are frequencies that have been reported in open literature and are used to avoid classification issues. Differences between these nominal values and actual source frequencies are small enough to be of little consequence to the output impact volumes.
- Source directivity – The source beam is modeled as the product of a horizontal beam pattern and a vertical beam pattern. Two parameters define the horizontal beam pattern:
- Horizontal beam width – Width of the source beam (degrees) in the horizontal plane (assumed constant for all horizontal steer directions).
- Horizontal steer direction – Direction in the horizontal in which the beam is steered relative to the direction in which the platform is heading

The horizontal beam has constant response across the width of the beam and with flat, 20-dB down sidelobes. (Note that steer directions ϕ, $-\phi$, $180^o - \phi$, and $180^o + \phi$ all produce equal impact volumes.)

Similarly, two parameters define the vertical beam pattern:

- Vertical beam width – Width of the source beam (degrees) in the vertical plane measured at the 3-dB down point. (The width is that of the beam steered towards broadside and not the width of the beam at the specified vertical steer direction.)
- Vertical steer direction – Direction in the vertical plane that the beam is steered relative to the horizontal (upward looking angles are positive).

To avoid sharp transitions that a rectangular beam might introduce, the power response at vertical angle θ is

$$\max \{ \sin^2 [n(\theta_s - \theta)] / [n \sin (\theta_s - \theta)]^2,\ 0.01 \}$$

where n = $180^o / \theta_w$ is the number of half-wavelength-spaced elements in a line array that produces a main lobe with a beam width of θ_w. θ_s is the vertical beam steer direction.

Ping spacing – Distance between pings. For most sources this is generally just the product of the speed of advance of the platform and the repetition rate of the source. Animal motion is generally of no consequence as long as the source motion is greater than the speed of the animal (nominally, three knots). For stationary (or nearly stationary) sources, the "average" speed of the animal is used in place of the platform speed. The attendant assumption is that the animals are all moving in the same constant direction.

These parameters are defined for each of the acoustic sources in the following table.

Table 6-4: Description of NAVSEA NUWC Keyport Range Complex Sources

Sonar Designation	Center Freq	Source Level	Emission Spacing	Vertical Directivity	Horizontal Directivity
S1	4.5 kHz	207 dB	0.2 m	20 deg	20 deg
S2	15 kHz	205 dB	1.9 m	30 deg	50 deg
S3	10 kHz	186 dB	45 m	60 deg	360 deg
S4	150 kHz	220 dB	1.9 m	9 deg	15 deg
S5	5 kHz	233 dB	93 m	60 deg	360 deg
S6	20 kHz	233 dB	45 m	20 deg	60 deg
S7	25 kHz	230 dB	540 m	20 deg	60 deg
S8	30 kHz	233 dB	617 m	20 deg	60 deg

6.18 Environmental Provinces

Propagation loss ultimately determines the extent of the Zone of Influence (ZOI) for a particular source activity. In turn, propagation loss as a function of range responds to a number of environmental parameters:

- water depth
- sound speed variability throughout the water column
- bottom geo-acoustic properties, and
- wind speed

Due to the importance that propagation loss plays in modeling effects, the Navy has over the last four to five decades invested heavily in measuring and modeling these environmental parameters. The result of this effort is the following collection of global databases of these environmental parameters, most of which are accepted as standards for all Navy modeling efforts.

- Water depth – Digital Bathymetry Data Base Variable Resolution (DBDBV)
- Sound speed – Generalized Digital Environmental Model (GDEM)
- Bottom loss – Low-Frequency Bottom Loss (LFBL), Sediment Thickness Database, and High-Frequency Bottom Loss (HFBL), and
- Wind speed – U.S. Navy Marine Climatic Atlas of the World

Representative environmental parameters are selected for each of the three operating areas: Dabob Bay, Keyport, and Quinault. Sources of local environmental-acoustic properties were supplemented with Navy Standard OAML data to determine model inputs for: bathymetry, sound-speed, and sediment properties.

The Dabob Bay and Keyport ranges are located inland with limited water-depth variability: the maximum water depth in Dabob Bay is approximately 200 meters; the maximum in the Keyport range is approximately 20 meters. The Quinault range, on the other hand, is located seaward of the US West Coast with depths greater than a kilometer.

Sound speed profiles for winter and summer from the OAML open-ocean database are presented in Figure 6-10. The winter profile is a classic half-channel (sound speed monotonically increasing with depth). The summer profile consists of a shallow surface duct over a modest thermocline. Individual profiles taken from World Ocean Data Base (NODC, 2005) for Dabob Bay and Keyport are generally consistent with these open-ocean profiles. Some of these profiles exhibit some effects of additional fresh-water near the surface; others have a little warmer surface layer than this summer profile. However, the truncated deep-water profiles are adequately representative of the inland ranges.

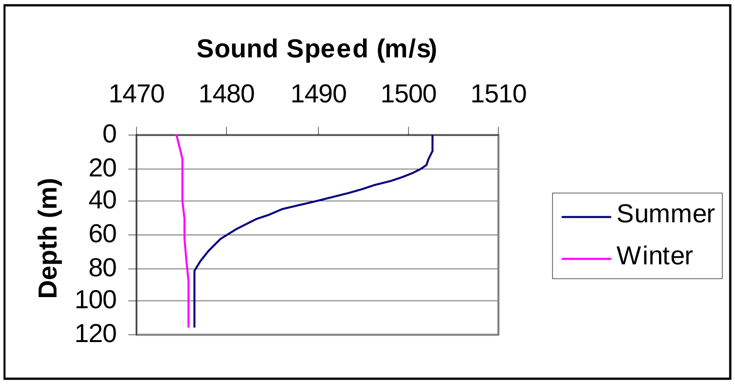


Figure 6-10: Typical Sound Speed Profiles

The bottom type in the Quinault range varies consistently with water depth. The shallower depths (less than 500 meters) tend to have sandy bottoms (HFBL class = 2); the deeper depths tend to be silt (HFBL class = 8)

The sediment type of the Dabob Bay and Keyport areas that we used for our modeling were different from those found in the Low Frequency Bottom Loss (LFBL) database or implied by the High-Frequency Bottom Loss (HFBL) database. Although the water depth of these areas can be greater that 50 m, the LFBL database assigned them the default “coarse sand” sediment type that was assigned to areas with water depth less than 50 m (Vidmar, 1994). Core data from these areas were collected as part or environmental monitoring (Llanso, 1998). Cores 14 and 15 from the northern parts of the Dabob Bay area indicated sediments with sands and silty sands. a silty sand sediment type was assigned to these areas (HFBL class = 2). Core 304R from the southern part of the Dabob Bay area indicated sediments with clay. A clay-silt sediment type (HFBL class = 4) was assigned to this area taking into account the transition from the more sandy northern area to the clay of the southern area. These assignments are consistent with the observation (Helton, 1976) that the boundary area between the northern and southern areas had sediments that were mostly mud with a small amount of sand. The Keyport area did not have any cores in the study area but had three cores surrounding the area: core 308R to the northwest indicated sand sediment; core 69 to the northeast indicated sand and silty sand sediments; and core 34 to the south indicated a clay sediment. Given the surrounding cores we assigned a sand-silt-clay sediment type to this area (HFBL class = 4).

The resulting environmental provinces used in this analysis are listed by range in Tables 6-5 through 6-7.

Table 6-5: Keyport Environmental Provinces

Province Number	Water Depth (m)	HFBL Class
K1	10	4
K2	20	4

Table 6-6: BBRC Environmental Provinces

Province Number	Water Depth (m)	HFBL Class
D1	10	2
D2	20	2
D3	50	2
D4	100	2
D5	200	2
D6	10	4
D7	20	4
D8	50	4
D9	100	4
D10	200	4

Table 6-7: QUTR Environmental Provinces

Province Number	Water Depth (m)	HFBL Class
Q1	10	2
Q2	20	2
Q3	50	2
Q4	100	2
Q5	200	2
Q6	500	8
Q7	1000	8
Q8	2000	8

Each of the ranges has an existing boundary and one or more alternative extensions. The Keyport range has a proposed extension to the east and south of the existing boundaries. In addition to the existing Dabob Bay boundary, there is one extension to the south and another extension to the south and the north. The Quinault range is expanded into a much larger deep-water region with three alternative surf zones (Kalaloch, Ocean City and Pacific Beach). The distribution of the environmental provinces across these various alternatives is provided in Tables 6-8 through 6-16.

Table 6-8: Distribution of Environments in Existing Keyport Range

Province Number	Frequency of Occurrence
K1	66.90 %
K2	33.10 %

Table 6-9: Distribution of Environments in Extended Keyport Range

Province Number	Frequency of Occurrence
K1	64.00 %
K2	36.00 %

Table 6-10: Distribution of Environments in Existing DBRC

Province Number	Frequency of Occurrence
D1	3.22 %
D2	7.76%
D3	38.58 %
D4	40.10 %
D5	10.34 %

Table 6-11: Distribution of Environments in DBRC with Southern Extension

Province Number	Frequency of Occurrence
D1	2.31 %
D2	5.57 %
D3	27.69 %
D4	28.78 %
D5	7.42 %
D6	0.26 %
D7	0.77 %
D8	4.05 %
D9	21.04 %
D10	2.11 %

Table 6-12: Distribution of Environments in DBRC with Northern and Southern Extensions

Province Number	Frequency of Occurrence
D1	2.21 %
D2	6.06 %
D3	30.22 %
D4	27.48 %
D5	7.09 %
D6	0.24 %
D7	0.74 %
D8	3.86 %
D9	20.09 %
D10	2.01 %

Table 6-13: Distribution of Environments in Existing QUTR

Province Number	Frequency of Occurrence
Q3	64.10 %
Q4	35.90 %

Table 6-14: Distribution of Environments in Extended QUTR with Kalaloch Surf Zone

Province Number	Frequency of Occurrence
Q1	0.24 %
Q2	2.70 %
Q3	15.51 %
Q4	17.41 %
Q5	7.94 %
Q6	10.56 %
Q7	28.02 %
Q8	17.62 %

Table 6-15: Distribution of Environments in Extended QUTR with Ocean City Surf Zone

Province Number	Frequency of Occurrence
Q1	0.14 %
Q2	2.80 %
Q3	15.51 %
Q4	17.41 %
Q5	7.94 %
Q6	10.56 %
Q7	28.02 %
Q8	17.62 %

Table 6-16: Distribution of Environments in New QUTR with Pacific Beach Surf Zone

Province Number	Frequency of Occurrence
Q1	0.07 %
Q2	2.77 %
Q3	15.91 %
Q4	17.34 %
Q5	7.91 %
Q6	10.52 %
Q7	27.92 %
Q8	17.56 %

6.19 Impact Volumes and Impact Ranges

Many naval actions include the potential to injure or harass marine animals in the neighboring waters through noise emissions. Given fixed harassment metrics and thresholds, the number of animals exposed to potential harassment in any such action is dictated by the propagation field and the characteristics of the noise source.

The expected impact volume associated with a particular activity is defined as the expected volume of water in which some acoustic metric exceeds a specified threshold. The product of this volume with a volumetric animal density yields the expected value of the number of animals exposed to that acoustic metric at a level that exceeds the threshold. There are two acoustic metrics for mid- and high-frequency acoustic sources effects: an energy term (energy flux density) or a pressure term (peak pressure). The thresholds associated with each of these metrics define the levels at which the animals exposed will experience some degree of harassment (ranging from behavioral change to hearing loss).

Impact volume is particularly relevant when trying to estimate the effect of repeated source emissions separated in either time or space. Impact range is defined as the maximum range at which a particular threshold is exceeded for a single source emission.

The two measures of potential harm to the marine wildlife due to mid- and high-frequency acoustic sources operations are the accumulated (summed over all source emissions) energy flux density received by the animal over the duration of the activity, and the peak pressure (loudest sound received) by the animal over the duration of the activity.

Regardless of the type of source, estimating the number of animals that may be harassed in a particular environment entails the following steps.

- Each source emission is modeled according to the particular operating mode of that source. The “effective” energy source level is computed by integrating over the bandwidth of the source, and scaling by the pulse length. The location of the source at the time of each emission must also be specified.
- For the relevant environmental acoustic parameters, transmission loss (TL) estimates are computed, sampling the water column over the appropriate depth and range intervals. TL data are sampled at the typical depth(s) of the source and at the nominal center frequency of the source.
- The accumulated energy and maximum sound pressure level (SPL) are sampled over a volumetric grid within the waters surrounding a source action. At each grid point, the received signal from each source emission is modeled as the source level reduced by the appropriate propagation loss from the location of the source at the time of each emission to that grid point. The maximum SPL field is calculated by taking the maximum level of the received signal over all emissions, and the energy field is calculated by summing the energy of the signal over all emissions, and adjusting for pulse length.
- The impact volume for a given threshold is estimated by summing the incremental volumes represented by each grid point for which the appropriate metric exceeds that threshold. For maximum SPL, calculation of the expected volume represented by each grid point depends on the maximum SPL at that point, and requires an extra step to apply the risk function.

Finally, the number of takes is estimated as the product (scalar or vector, depending upon whether an animal density depth distribution is available) of the impact volume and the animal densities.

This section describes in detail the process of computing impact volumes for acoustic sources. The relevant assumptions associated with this approach and the limitations that are implied are also presented. The final step, using the impact volumes to compute the number of harassments, is discussed in subsection 6.19.1.

6.19.1 Computing Impact Volumes for Active Sonars

This section provides a detailed description of the approach taken to compute impact volumes for mid- and high-frequency acoustic sources. Included in this discussion are:

- Identification of the underwater propagation model used to compute transmission loss data, a listing of the source-related inputs to that model, and a description of the output parameters that are passed to the energy accumulation algorithm.
- Definitions of the parameters describing each acoustic source type.
- Description of the algorithms and sampling rates associated with the energy accumulation algorithm.

Transmission Loss Calculations

Transmission loss (TL) data are pre-computed for each of two seasons in each of the environmental provinces described in the previous subsection using the Gaussian Ray Bundle (GRAB) propagation loss model (Keenan, 2000). The TL output consists of a parametric description of each significant eigenray (or propagation path) from source to a grid point. The description of each eigenray includes the departure angle from the source (used to model the source vertical directivity later in this process), the propagation time from the source to the grid point (used to make corrections to absorption loss for minor differences in frequency and to incorporate a surface-image interference correction at low frequencies), and the transmission loss suffered along the eigenray path.

The sources' center frequencies used in the TL calculations are specified in Table 6-17.

Table 6-17: TL Frequency by Source Type

Source	Frequency
S1	4.5 kHz
S2	15 kHz
S3	10 kHz
S4	150 kHz
S5	5 kHz
S6	20 kHz
S7	25 kHz
S8	30 kHz

It is important to note that for low-power and very high-frequency systems impact ranges are short, and any propagation modeling approach will yield approximately spherical spreading plus absorption. Hence, most short-range cases produce impact volumes virtually independent of location.

The eigenray data for a single GRAB model run are sampled at uniform increments in range out to a maximum range for a specific "grid point" (or "target" in GRAB terminology) depth. Multiple GRAB runs are made to sample the animal depth dependence. The depth and range sampling parameters are summarized in Table 6-18.

Table 6-18: TL Depth and Range Sampling Parameters by Sonar Type

Source	Range Step	Depth Step
S1	10 m	5 m to 1 km, 10 m thereafter
S2	10 m	5 m to 1 km, 10 m thereafter
S3	10 m	5 m to 1 km, 10 m thereafter
S4	10 m	5 m to 1 km, 10 m thereafter
S5	10 m	5 m to 1 km, 10 m thereafter
S6	10 m	5 m to 1 km, 10 m thereafter
S7	10 m	5 m to 1 km, 10 m thereafter
S8	10 m	5 m to 1 km, 10 m thereafter

Although GRAB provides the option of including the effect of source directivity in its eigenray output, this capability is not exercised. By preserving data at the eigenray level, this allows source directivity to be applied later in the process and results in fewer TL calculations.

Energy Summation

The summation of energy flux density over multiple pings in a range-independent environment requires less calculation that the risk function computations for the SPL metric. A volumetric grid that covers the waters in and around the area of sonar operation is initialized. The source then begins its set of pings. For the first ping, the TL from the source to each grid point is determined (summing the appropriate eigenrays after they have been modified by the vertical beam pattern), the “effective” energy source level is reduced by that TL, and the result is added to the accumulated energy flux density at that grid point. After each grid point has been updated, the accumulated energy at grid points in each depth layer is compared to the specified threshold. If the accumulated energy exceeds that threshold, then the incremental volume represented by that grid point is added to the impact volume for that depth layer. Once all grid points have been processed, the resulting sum of the incremental volumes represents the impact volume for one ping.

The source is then moved along one of the axes in the horizontal plane by the specified ping separation range and the second ping is processed in a similar fashion. Again, once all grid points have been processed, the resulting sum of the incremental volumes represents the impact volume for two pings. This procedure continues until the maximum number of pings specified has been reached.

Selecting the size of the volumetric grid over which to accumulate energy requires balancing of two considerations. The volume must be large enough to contain all volumetric cells for which the accumulated energy is likely to exceed the threshold but not so large as to make the energy accumulation computationally unmanageable.

Determining the size of the volumetric grid begins with an iterative process to determine the lateral extent to be considered. Unless otherwise noted, throughout the selection process the source is treated as omni directional and the only animal depth that is considered is the TL target depth that is closest to the source depth (placing source and receiver at the same depth is generally an optimal TL geometry).

The first step is to determine the impact range (R_{MAX}) for a single ping. The impact range in this case is the maximum range at which the effective energy source level reduced by the transmission loss is greater than the threshold. Next, the source is moved along a straight-line track and energy flux density is accumulated at a point that has a CPA range of R_{MAX} at the mid-point of the source track. That total energy flux density summed over all pings is then compared to the prescribed threshold. If it is greater than the threshold (which, for the first R_{MAX}, it must be) then R_{MAX} is increased by ten percent, the accumulation process is repeated, and the total energy is again compared to the threshold. This continues until R_{MAX} grows large enough to ensure that the accumulated energy flux density at that lateral range is less than the threshold. The lateral range dimension of the volumetric grid is then set at twice R_{MAX}, with the grid centered along the source track. In the direction of advance for the source, the volumetric grid extends of the interval from [$-R_{MAX}$, 3 R_{MAX}] with the first source position located at zero in this dimension. Note that the source motion in this direction is limited to the interval [0, 2 R_{MAX}]. Once the source reaches 2 R_{MAX} in this direction, the incremental volume contributions have approximately reached their asymptotic limit and further pings add essentially the same amount. This geometry is demonstrated in Figure A-2 below.

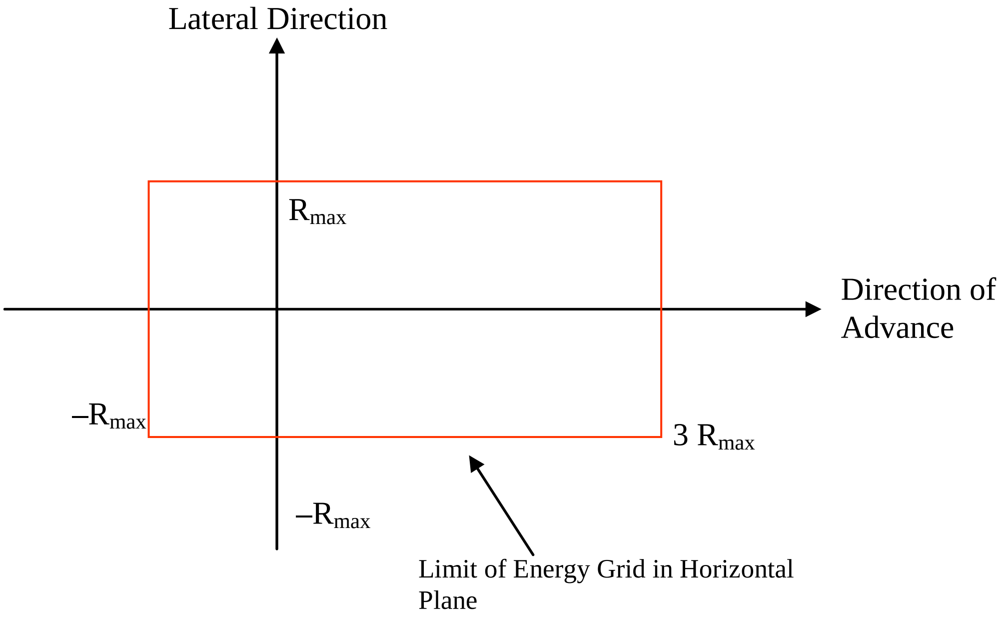


Figure 6-11: Horizontal Plane of Volumetric Grid for Omni Directional Source.

If the source is directive in the horizontal plane, then the lateral dimension of the grid may be reduced and the position of the source track adjusted accordingly. For example, if the main lobe of the horizontal source beam is limited to the starboard side of the source platform, then the port side of the track is reduced substantially as demonstrated in Figure A-3.

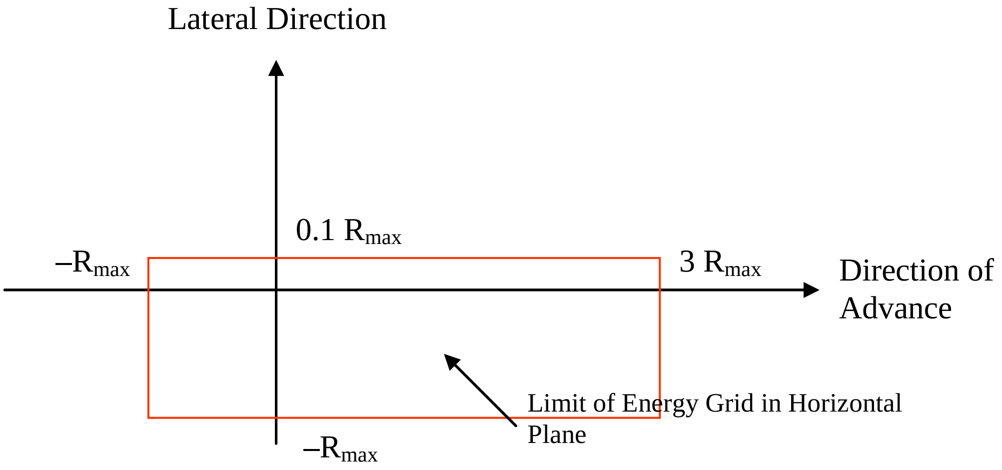


Figure 6-12: Horizontal Plane of Volumetric Grid for Starboard Beam Source.

Once the extent of the grid is established, the grid sampling can be defined. In both dimensions of the horizontal plane the sampling rate is approximately $R_{MAX}/100$. The round-off error associated with this sampling rate is roughly equivalent to the error in a numerical integration to determine the area of a circle with a radius of R_{MAX} with a partitioning rate of $R_{MAX}/100$ (approximately one percent). The depth-sampling rate of the grid is comparable to the sampling rates in the horizontal plane but discretized to match an actual TL sampling depth. The depth-sampling rate is also limited to no more that ten meters to ensure that significant TL variability over depth is captured.

Impact Volume per Run

The impact volume for a source moving relative to the animal population increases with each additional ping. The rate at which the impact volume increases varies with a number of parameters but eventually approaches some asymptotic limit. Beyond that point the increase in impact volume becomes essentially linear as depicted in Figure 6-13.

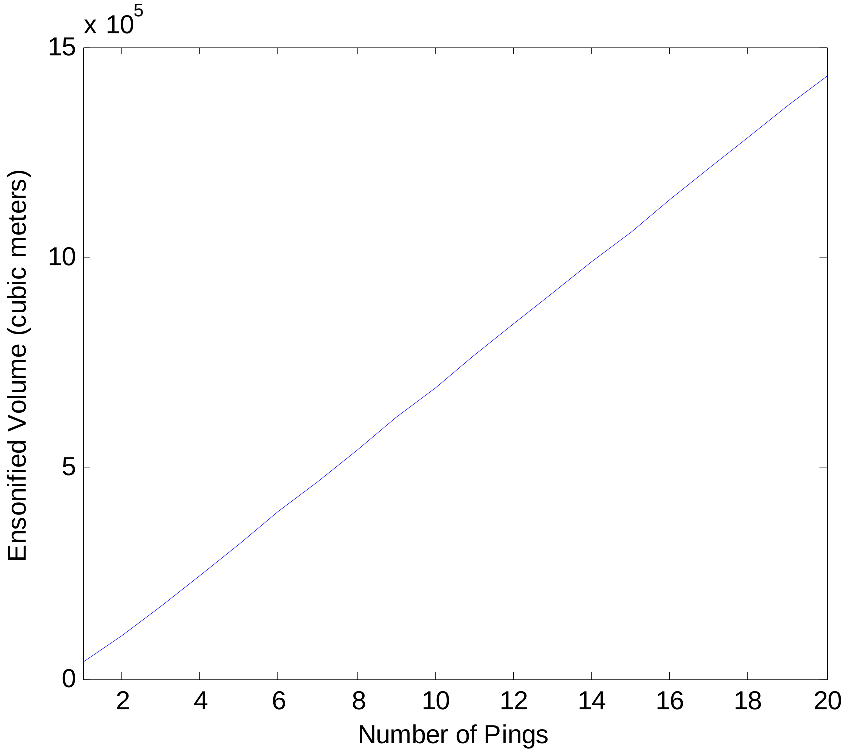


Figure 6-13: 195 dB Volume by Ping for S5 in Environment 4, between 47.5 m and 52.5 m

The value of the ensonification after the last ping in the run is reached gives the impact volume for the given depth increment. Completing this calculation for all depths in a province, for a given source, gives the run's impact volume vector, v_n, which contains the hourly impact volumes by depth for province n. Figure 6-14 provides an example of an hourly impact volume vector for the same situation as Figure 6-13.

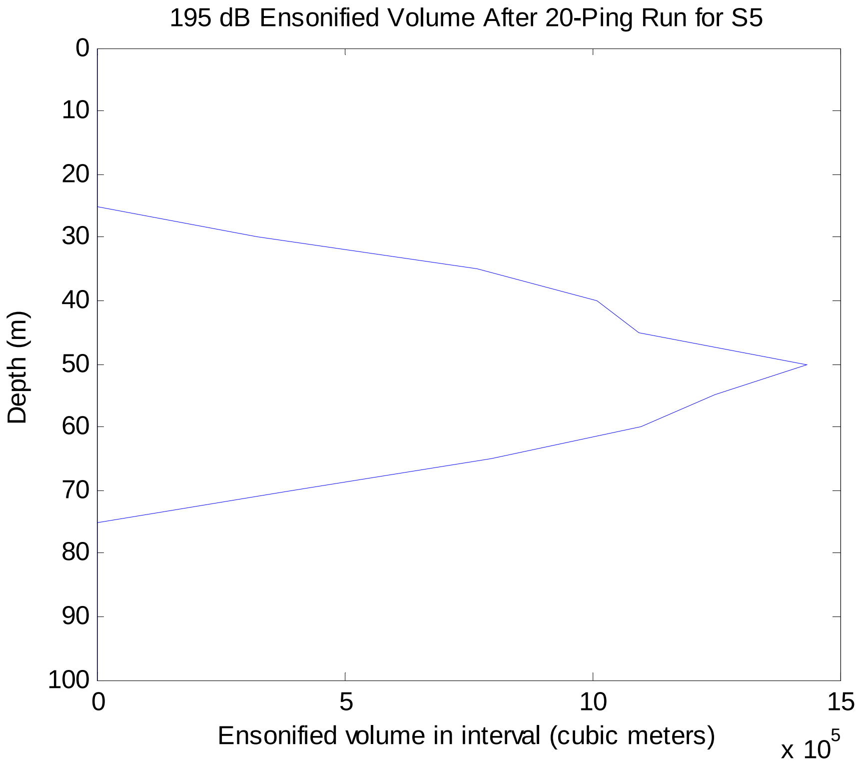


Figure 6-14:Example of an Impact Volume Vector

6.19.2 Impact Volume by Region

As discussed, all the Keyport existing and proposed ranges are made up of a combination of twenty environmental provinces. Some, such as the existing Keyport Range, only two of the environments are found, and in some, such as DBRC with northern and southern extensions, up to ten are found. In any of the alternatives, the per-run impact volume vector for operations involving any particular source at a given site is a linear combination of the twenty impact volume vectors with the weighting determined by the distribution of those twenty environmental provinces within that site. Unique impact volume vectors for winter and summer are calculated for each type of source and each metric/threshold combination.

6.20 Risk Function: Theoretical and Practical Implementation

This section discusses the recent addition of a risk function threshold to acoustic effects analysis procedure. This approach includes two parts, a new metric, and a function to map exposure level under the new metric to probability of harassment. What these two parts mean, how they affect exposure calculations, and how they are implemented are the objects of discussion.

6.20.1 Thresholds and Metrics

The term "thresholds" is broadly used to refer to both thresholds and metrics. The difference, and the distinct roles of each in effects analyses, will be the foundation for understanding the risk-function approach, putting it in perspective, and showing that, conceptually, it is similar to past approaches.

Sound is a pressure wave, so at a certain point in space, sound is simply rapidly changing pressure. Pressure at a point is a function of time. Define p(t) as pressure (in micropascals) at a given point at time t (in seconds); this function is called a "time series." Figure 6-15 gives the time series of the first "hallelujah" in Handel's Hallelujah Chorus.

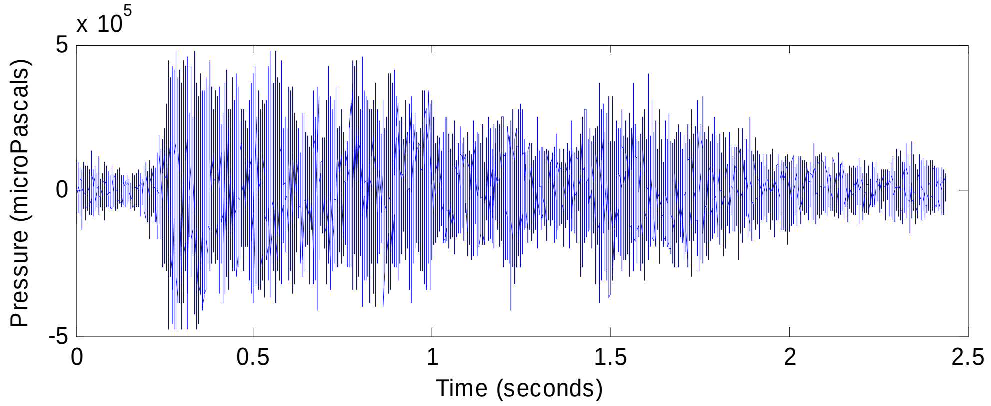


Figure 6-15: Time Series

The time-series of a source can be different at different places. Therefore, sound, or pressure, is not only a function of time, but also of location. Let the function p(t), then be expanded to p(t;x,y,z) and denote the time series at point (x,y,z) in space. Thus the series in Figure A-7, p(t) is for a given point (x,y,z). At a different point in space, it would be different.

Assume that the location of the source is (0,0,0) and this series is recorded at (0,10,-4). The time series above would be p(t;0,10,-4) for 0<t<2.5.

As in Figure 6-15, pressure can be positive or negative, but usually the function is squared so it is always positive, this makes integration meaningful. Figure 6-16 is $p^2(t;0,10,-4)$.

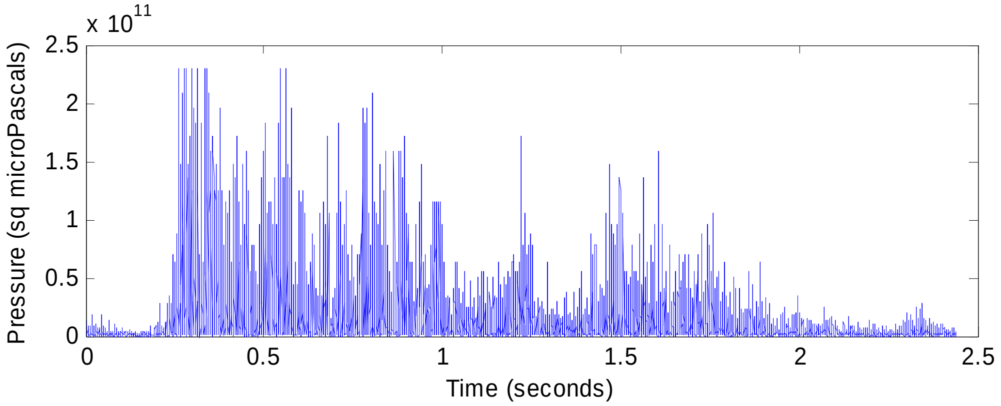


Figure 6-16: Time Series Squared

The metric chosen to evaluate the sound field at the end of this first "hallelujah" determines how the time series is summarized from thousands of points, as in Figure 6-16, to a single value for each point (x,y,z) in the space. The metric essentially "boils down" the four dimensional p(t,x,y,z) into a three dimensional function m(x,y,z) by dealing with time. There is more than one way to summarize the time component, so there is more than one metric.

Max SPL

One way to summarize $p^2(t;x,y,z)$ to one number over the 2.5 seconds is to only report the maximum value of the function over time or,

$$SPL_{\max} = \max\left\{p^2(t,x,y,z)\right\} \text{ for } 0<t<2.5$$

The $SPL_{\max}$ for this snippet of the Hallelujah Chorus is $2.3\times10^{11}\ \mu Pa^2$ and occurs at 0.2825 seconds, as shown in Figure 6-17.

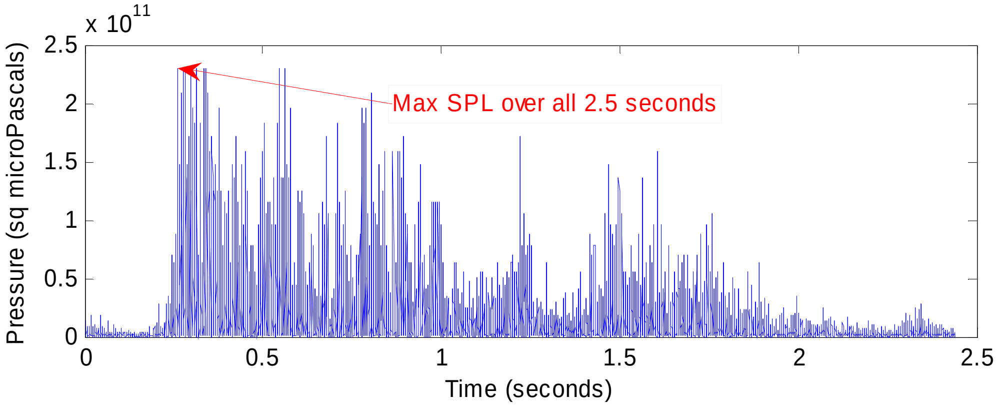


Figure 6-17: Max SPL of Time Series Squared

Integration

$SPL_{\max}$ is not necessarily influenced by the duration of the sound (2.5 seconds in this case). Integrating the function over time does take this duration into account. A simple integration of $p^2(t;x,y,z)$ over t is common and usually called "energy."

$$Energy = \int_0^T p^2(t,x,y,z)dt$$

where T is the maximum time of interest, in this case 2.5. The energy for this snippet of the Hallelujah Chorus is $1.24\times10^{11}\ \mu Pa\cdot s$.

After p(t) is determined (i.e., when the stimulus is over), propagation models can be used to determine p(t;x,y,z) for every point in the vicinity and for a given metric. Define

$m_a(x,y,z,T) =$ value of metric "a" at point (x,y,z) after time T

So,

$$m_{energy}(x,y,z;T) = \int_0^T p(t)^2\,dt$$

$$m_{\max SPL}(x,y,z;T) = \max(p(t))\ over\ [0,T]$$

Since modeling is concerned with the effects of an entire event, T is usually implicitly defined: a number that captures the duration of the event. This means that $m_a(x,y,z)$ is assumed to be measured over the duration of the received signal.

Three Dimensions Versus Two Dimensions

To further reduce the calculation burden, it is possible to reduce the domain of $m_a(x, y, z)$ to two dimensions by defining $m_a(x, y) = \max\{m_a(x, y, z)\}$ over all z. This reduction is not used for this analysis, which is exclusively three-dimensional.

Threshold

For a given metric, a threshold is a function that gives the probability of exposure at every value of m_a. This threshold function will be defined as

$$D(m_a(x, y, z)) = \Pr(effect\ at\ m_a(x, y, z))$$

The domain of D is the range of $m_a(x, y, z)$, and its range is the number of thresholds.

An example of threshold functions is the Heavyside (or unit step) function, currently used to determine permanent and temporary threshold shift (PTS and TTS) in cetaceans. For PTS, the metric is $m_{energy}(x, y, z)$, defined above, and the threshold function is a Heavyside function with a discontinuity at 215 dB, shown in Figure 6-18.

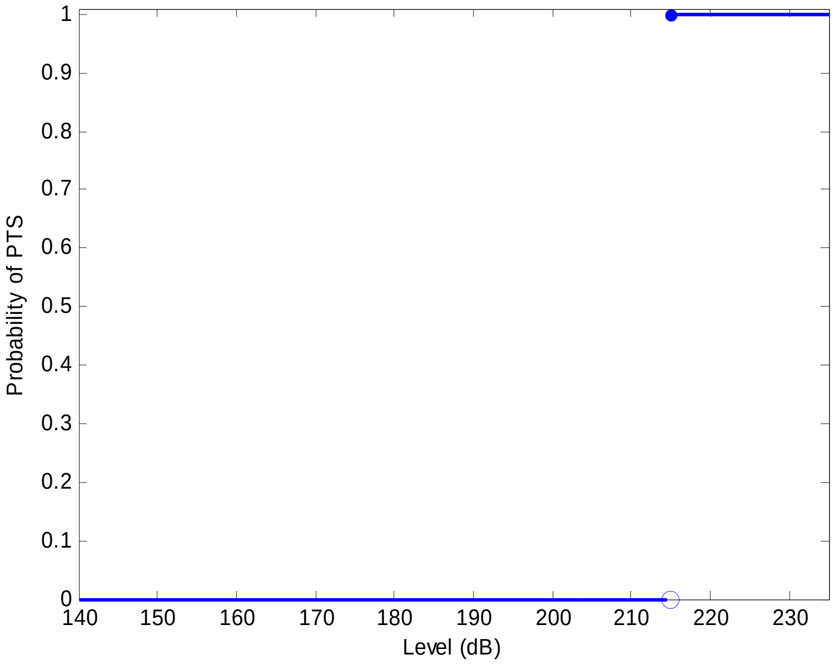


Figure 6-18: PTS Heavyside Threshold Function

Mathematically, this D is defined as:

$$D(m_{energy}) = \begin{cases} 0 \;\; for \; m_{energy} < 215 \\ 1 \;\; for \; m_{energy} \geq 215 \end{cases}$$

Any function can be used for D, as long as its range is in [0,1]. The risk functions are adapted from Feller (1968) and have been discussed in detail in Section 6.15. While a Heavyside function is specified by a single parameter, the discontinuity, the risk function requires three parameters: the basement, the distance between basement and 50% effect, and the steepness parameter. Mathematically, these risk functions are defined as

$$D(m_{\max SPL}) = \begin{cases} \dfrac{1}{1+\left(\dfrac{K}{m-B}\right)^{A}} \;\; for \; m_a > B \\ 0 \;\; for \; m_{\max SPL} \leq B \end{cases}$$

where B=cutoff (or basement), K=the difference in dB between the level that causes 50% harassment, and A=”steepness” factor. Alternatively this equation can be written as follows:

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

for D=R and *m*=L and for the case *m*>B. This mathematical function is used to predict MMPA Level B behavioral harassment as adapted from the solution in Feller (1968) and as used in DON (2001), per CNO N45 direction. The risk function used for odontocetes and pinnipeds uses the parameters B=120, K=45, and A=10. For mysticetes, the parameters used were B=120, K=45, and A=8. Harbor porpoises are a special case. Though the metric for their behavioral harassment is SPL, their risk function is a heavyside function with a discontinuity at 120 dB SPL. In this analysis, this is the only species that uses a step function is used to determine the threshold for behavioral harassment.

Multiple Metrics and Thresholds

It is possible to have more than one metric, and more than one threshold in a given metric. For example, in this document, killer whales have two metrics (energy and max SPL), and three thresholds (two for energy, one for max SPL). The energy thresholds are heavyside functions, as described above, with discontinuities at 215 and 195 for PTS and TTS respectively. The max SPL variable-level threshold determines behavioral harassment, and is defined by the odontocete risk function (described above, with B=120, K=45, and A=10).

6.20.2 Calculation of Expected Exposures

Determining the number of expected exposures for disturbance is the object of this analysis.

Expected exposures in volume V is $\int_V \rho(V) D(m_a(V)) dV$

For this analysis, $m_a = m_{\max SPL}$, so

$$\int_V \rho(V) D(m_a(V)) dV = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \rho(x,y,z) D(m_{\max SPL}(x,y,z)) dx dy dz$$

In this analysis, the densities are constant over the x/y plane, and the z dimension is always negative, so this reduces to

$$\int_{-\infty}^{0} \rho(z) \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z))dxdydz$$

6.20.3 Numeric Implementation

Numeric integration of $\int_{-\infty}^{\infty} \rho(z) \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z))dxdydz$ can be involved because, although the bounds are infinite, D is non-negative out to 120 dB, which, depending on the environmental specifics, can drive propagation loss calculations and their numerical integration out to over 100 km.

The first step in the solution is to separate out the x/y-plane portion of the integral:

Define f(z)= $\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z))dxdy$.

Calculation of this integral is the most involved and time consuming part of the calculation. Once it is complete,

$$\int_{-\infty}^{0} \rho(z) \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z))dxdydz = \int_{-\infty}^{0} \rho(z) f(z)dz\,,$$

which, when numerically integrated, is a simple dot product of two vectors.

Thus, the calculation of f(z) requires the majority of the computation resources for the numerical integration. The rest of this section presents a brief outline of the steps to calculate f(z) and preserve the results efficiently.

The concept of numerical integration is, instead of integrating over continuous functions, to sample the functions at small intervals and sum the samples to approximate the integral. The smaller the size of the intervals, the closer the approximation, but the longer the calculation, so a balance between accuracy and time is determined in the decision of step size. For this analysis, z is sampled in 5 meter steps to 1000 meters in depth and 10 meter steps to 2000 meters, which is the limit of animal depth in this analysis. The step size for x is 5 meters, and y is sampled with an interval that increases as the distance from the source increases. Mathematically,

$$\begin{aligned} &z \in Z = \{0,5,...1000,1010,...,2000\} \\ &x \in X = \{0,\pm5,...,\pm5k\} \\ &y \in Y = \{0,\pm5(1.005)^0,5\pm(1.005)^1,\pm5(1.005)^2,...,5(1.005)^j\} \end{aligned}$$

for integers k,j, which depend on the propagation distance from the source. For this analysis, k=20,000 and j=600

With these steps, $f(z_0) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z_0))dxdy$ is approximated as

$$\sum_{z\in Y}\sum_{x\in X} D(m_{\max SPL}(x,y,z_0))\Delta x\Delta y$$

where x,y are defined as above.

This calculation must be repeated for each $z_0 \in Z$, to build the discrete function f(z).

With the calculation of f(z) complete, the integral of its product with $\rho(z)$ must be calculated to complete evaluation of

$$\int_{-\infty}^{\infty}\rho(z)\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z))dxdydz = \int_{-\infty}^{0}\rho(z)f(z)dz$$

Since f(z) is discrete, and $\rho(z)$ can be readily made discrete, $\int_{-\infty}^{0}\rho(z)f(z)dz$ is approximated numerically as $\sum_{z\in Z}\rho(z)f(z)$, a dot product.

Preserving Calculations for Future Use

Calculating f(z) is the most time-consuming part of the numerical integration, but the most time-consuming portion of the entire process is calculating $m_{\max SPL}(x,y,z)$ over the area range required to reach the basement value. The calculations usually require propagation estimates out to over 65 km, and those estimates, with the beam pattern, are used to construct a sound field that extends 65 km x 65 km = 4225 sq km, with a calculation at the steps for every value of x and y, defined above. This is repeated for each depth, to a maximum of 2000 meters.

Saving the entire $m_{\max SPL}$ for each z is unrealistic, requiring great amounts of time and disk space. Instead, the different levels in the range of $m_{\max SPL}$ are sorted into 0.5 dB wide bins; the volume of water at each bin level is taken from $m_{\max SPL}$, and associated with its bin. Saving this, the amount of water ensonified at each level, at 0.5 dB resolution, preserves the ensonification information without using the space and time required to save $m_{\max SPL}$ itself. Practically, this is a histogram of occurrence of level at each depth, with 0.5 dB bins. Mathematically, this is simply defining the discrete functions $V_z(L)$, where $L = \{.5a\}$ for every positive integer a, for all $z \in Z$. These functions, or histograms, are saved for future work. The information lost by saving only the histograms is *where* in space the different levels occur, although *how often* they occur is saved. But the thresholds (risk functions) are purely a function of level, not location, so this information is sufficient to calculate f(z).

Applying the risk function to the histograms is a dot product:

$$\sum_{\ell\in L_1} D(\ell)V_{z_0}(\ell) \approx \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z_0))dxdy$$

Once the histograms are saved, neither $m_{\max SPL}(x,y,z)$ nor f(z) must be recalculated to generate $\int_{-\infty}^{0}\rho(z)\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z))dxdydz$ for a new threshold function.

For the interested reader, the following section includes an in-depth discussion of the method, software, and other details of the f(z) calculation.

Software Detail

The risk function metric uses the Feller function to determine the probability that an animal is affected by a given sound pressure level, and the minimum level at which harassment could occur. The acoustic quantity of interest is the maximum sound pressure level experienced over multiple pings in a range-independent environment. The procedure for calculating the impact volume at a given depth is relatively simple. In brief, given the sound pressure level of the source and the transmission loss (TL) curve, the sound pressure level is calculated on a volumetric grid. For a given depth, volume associated with a sound pressure level interval is calculated. Then, this volume is multiplied by the probability that an animal will be affected by that sound pressure level. This gives the impact volume for that depth, that can be multiplied by the animal densities at that depth, to obtain the number of animals affected at that depth. The process repeats for each depth to construct the impact volume as a function of depth.

The case of a single emission, one ping, illustrates the computational process in more detail. First, the sound pressure levels are segregated into a sequence of bins that cover the range encountered in the area. The sound pressure levels are used to define a volumetric grid of the local sound field. The impact volume for each depth is calculated as follows: for each depth in the volumetric grid, the sound pressure level at each x/y plane grid point is calculated using the sound pressure level of the source, the TL curve, the horizontal beam pattern of the source, and the vertical beam patterns of the source. The sound pressure levels in this grid become the bins in the volume histogram. Figure 6-19 shows a volume histogram for a low-power sonar. Level bins are 0.5 dB in width and the depth is 50 meters in an environment with water depth of 100 meters. The oscillatory structure at very low levels is due the flattening of the TL curve at long distances from the source, which magnifies the fluctuations of the TL as a function of range. The expected impact volume for a given level at a given depth is calculated by multiplying the volume in each level bin by the risk function at that level. Total expected impact volume for a given depth is the sum of these expected volumes. Figure 6-20 is an example of the impact volume as a function of depth at a water depth of 100 meters.

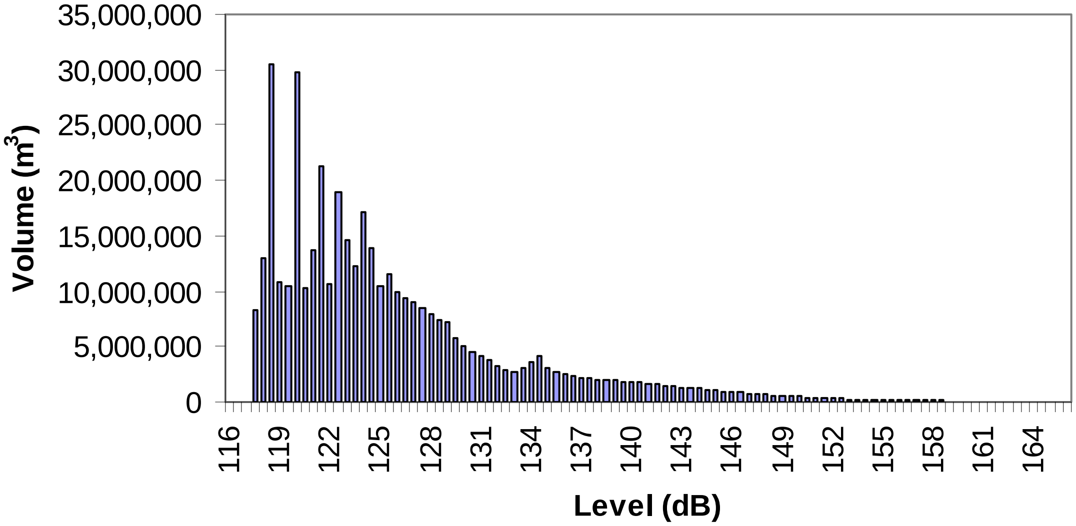


Figure 6-19: Example of a Volume Histogram

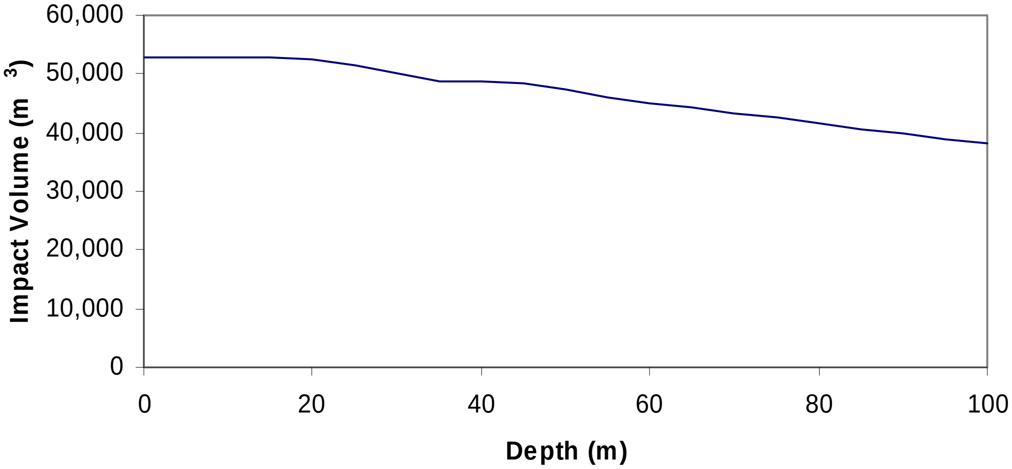


Figure 6-20: Example of the Dependence of Impact Volume

The volumetric grid covers the waters in and around the area of sonar operation. The grid for this analysis has a uniform spacing of 5 meters in the x-coordinate and a slowly expanding spacing in the y-coordinate that starts with 5 meters spacing at the origin. The growth of the grid size along the y-axis is a geometric series. Each successive grid size is obtained from the previous by multiplying it by 1+Ry, where Ry is the y-axis growth factor. This forms a geometric series. The n^{th} grid size is related to the first grid size by multiplying by $(1+Ry)^{(n-1)}$. For an initial grid size of 5 meters and a growth factor of 0.005, the 100th grid increment is 8.19 meters. The constant spacing in the x-coordinate allows greater accuracy as the source moves along the x-axis. The slowly increasing spacing in y reduces computation time, while maintaining accuracy, by taking advantage of the fact that TL changes more slowly at longer distances from the source. The x-and y-coordinates extend from –Rmax to +Rmax, where Rmax is the maximum range used in the TL calculations. The z direction uses a uniform spacing of 5 meters down to 1000 meters and 10 meters from 1000 to 2000 meters. This is the same depth mesh used for the effective energy metric as described above. The depth mesh does not extend below 2000 meters, on the assumption that animals of interest are not found below this depth.

The next three figures indicate how the accuracy of the calculation of impact volume depends on the parameters used to generate the mesh in the horizontal plane. Figure 6-21 shows the relative change of impact volume for one ping as a function of the grid size used for the x-axis. The y-axis grid size is fixed at 5m and the y-axis growth factor is 0, i.e., uniform spacing. The impact volume for a 5 meters grid size is the reference. For grid sizes between 2.5 and 7.5 meters, the change is less than 0.1%. A grid size of 5 meters for the x-axis is used in the calculations. Figure 6-22 shows the relative change of impact volume for one ping as a function of the grid size used for the y-axis. The x-axis grid size is fixed at 5 meters and the y-axis growth factor is 0. The impact volume for a 5 meters grid size is the reference. This figure is very similar to that for the x-axis grid size. For grid sizes between 2.5 and 7.5 meters, the change is less than 0.1%. A grid size of 5 meters is used for the y-axis in our calculations. Figure 6-23 shows the relative change of impact volume for one ping as a function of the y-axis growth factor. The x-axis grid size is fixed at 5 meters and the initial y-axis grid size is 5 meters. The impact volume for a growth factor of 0 is the reference. For growth factors from 0 to 0.01, the change is less than 0.1%. A growth factor of 0.005 is used in the calculations.

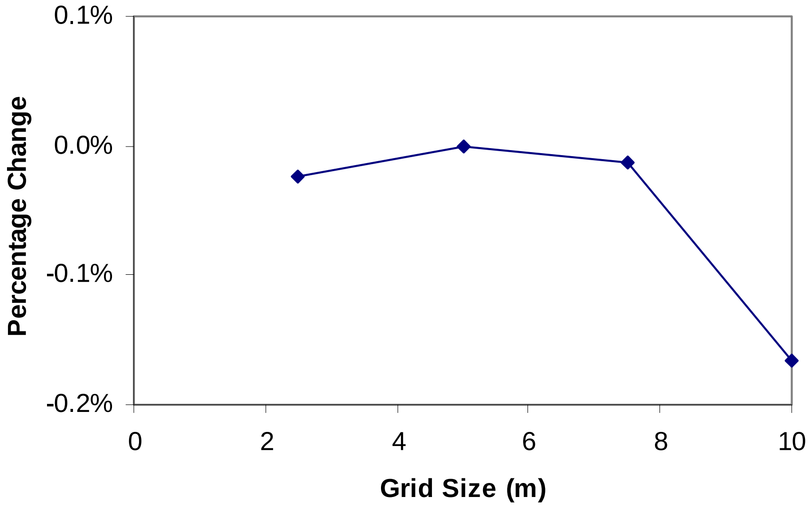


Figure 6-21: Change of Impact Volume as a Function of X-Axis Grid Size

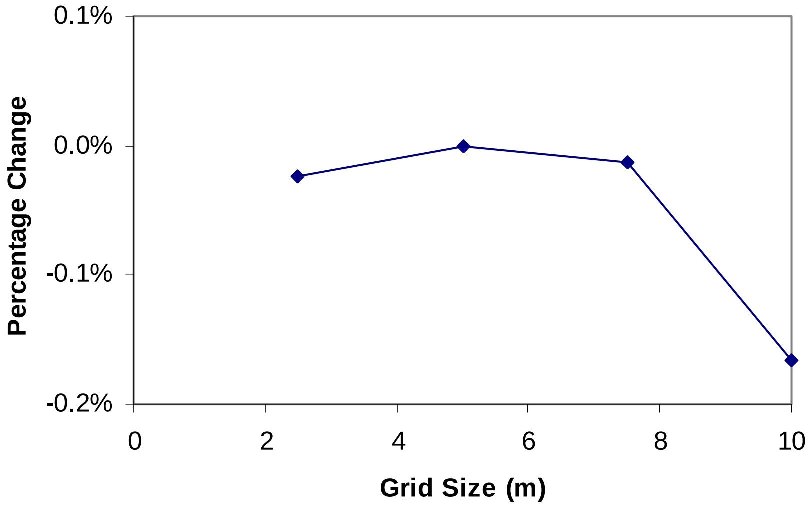


Figure 6-22: Change of Impact Volume as a Function of Y-Axis Grid Size

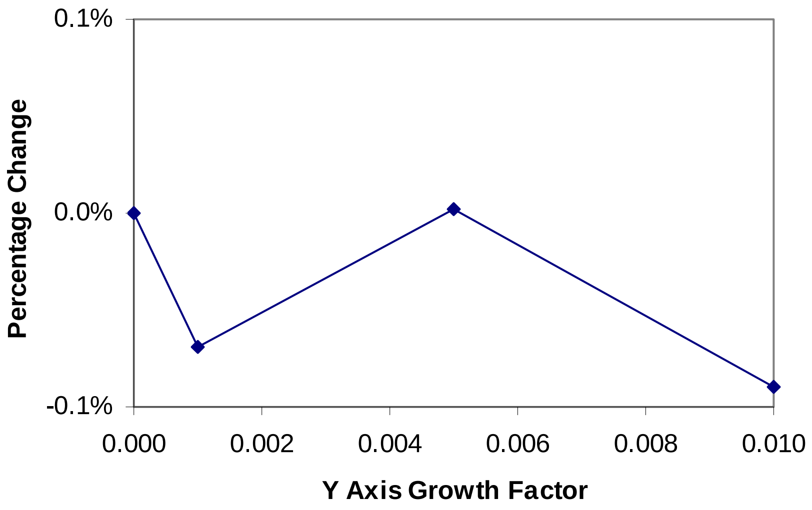


Figure 6-23: Change of Impact Volume as a Function of Y-Axis Growth Factor

Another factor influencing the accuracy of the calculation of impact volumes is the size of the bins used for sound pressure level. The sound pressure level bins extend from 100 dB (far lower than required) up to 300 dB (much higher than that expected for any sonar system). Figure 6-24 shows the relative change of impact volume for one ping as a function of the bin width. The x-axis grid size is fixed at 5 meters the initial y-axis grid size is 5 meters, and the y-axis growth factor is 0.005. The impact volume for a bin size of 0.5 dB is the reference. For bin widths from 0.25 dB to 1.00 dB, the change is about 0.1%. A bin width of 0.5 is used in our calculations.

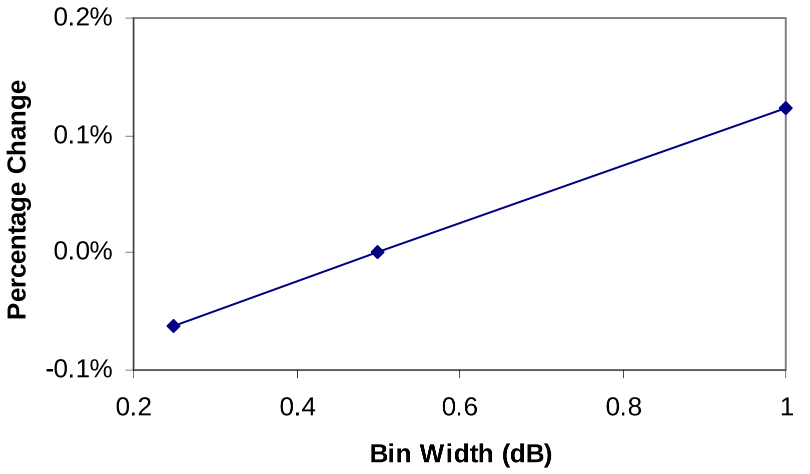


Figure 6-24: Change of Impact Volume as a Function of Bin Width

Two other issues for discussion are the maximum range (Rmax) and the spacing in range and depth used for calculating TL. The TL generated for the energy accumulation metric is used for risk function analysis. The same sampling in range and depth is adequate for this metric because it requires a less demanding computation (i.e., maximum value instead of accumulated energy). Using the same value of

Rmax needs some discussion since it is not clear that the same value can be used for both metrics. Rmax, for a given source, was set so that the TL at Rmax is more than what is needed for the source level to reach the basement value of 120 dB SPL.

The process of obtaining the maximum sound pressure level at each grid point in the volumetric grid is straightforward. The active sonar starts at the origin and moves at constant speed along the positive x-axis emitting a burst of energy, a ping, at regularly spaced intervals. For each ping, the distance and horizontal angle connecting the sonar to each grid point is computed. Calculating the TL from the source to a grid point has several steps. The TL is made up of the sum of many eigenrays connecting the source to the grid point. The beam pattern of the source is applied to the eigenrays based on the angle at which they leave the source. After summing the vertically beamformed eigenrays on the range mesh used for the TL calculation, the vertically beamformed TL for the distance from the sonar to the grid point is derived by interpolation. Next, the horizontal beam pattern of the source is applied using the horizontal angle connecting the sonar to the grid point. To avoid problems in extrapolating TL, only use grid points with distances less than R_{max} are used. To obtain the sound pressure level at a grid point, the sound pressure level of the source is reduced by that TL. For the first ping, the volumetric grid is populated by the calculated sound pressure level at each grid point. For the second ping and subsequent pings, the source location increments along the x-axis by the spacing between pings and the sound pressure level for each grid point is again calculated for the new source location. Since the risk function metric uses the maximum of the sound pressure levels at each grid point, the newly calculated sound pressure level at each grid point is compared to the sound pressure level stored in the grid. If the new level is larger than the stored level, the value at that grid point is replaced by the new sound pressure level.

For each bin, a volume is determined by summing the ensonified volumes with a maximum SPL in the bin's interval. This forms the volume histogram shown in Figure 6-19. Multiplying by the risk function for the level at the center of a bin gives the impact volume for that bin. The result can be seen in Figure 6-20, which is an example of the impact volume as a function of depth.

The impact volume for a source moving relative to the animal population increases with each additional ping. The rate at which the impact volume increases for the risk function metric is essentially linear with the number of pings. Figure 6-25 shows the dependence of impact volume on the number of pings. The function is linear; the slope of the line at a given depth is the impact volume added per ping. This number multiplied by the number of pings in an hour gives the hourly impact volume for the given depth increment. Completing this calculation for all depths in a province, for a given source, gives the hourly impact volume vector which contains the hourly impact volumes by depth for a province. Figure 6-26 provides an example of an impact volume vector for a particular environment. Given the speed of the acoustic source, the impact volume vector could be displayed as the impact volume vector per kilometer of track. For the NAVSEA NUWC Keyport Range Complex, per-run impact volume vectors are used to calculate effects per run, instead of hourly impact vectors, but the below figures demonstrate the influence of ping number on impact volumes.

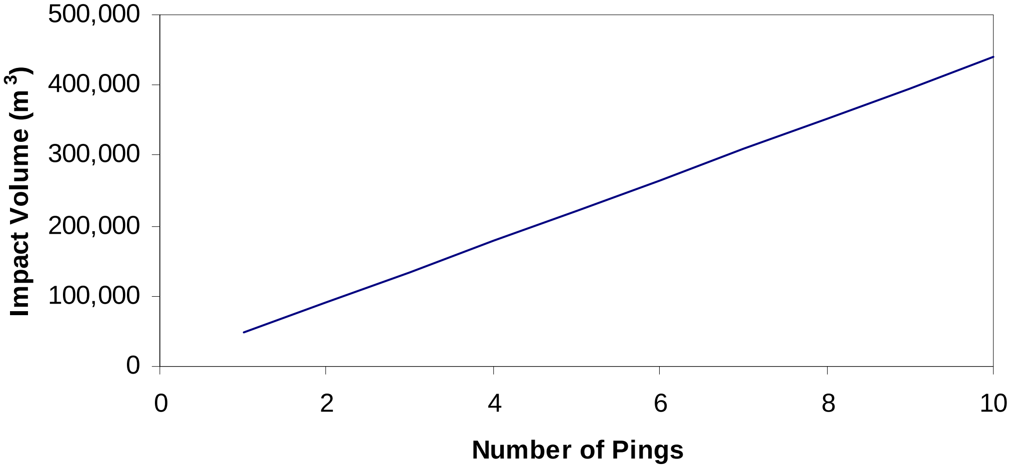


Figure 6-25: Dependence of Impact Volume on the Number of Pings.

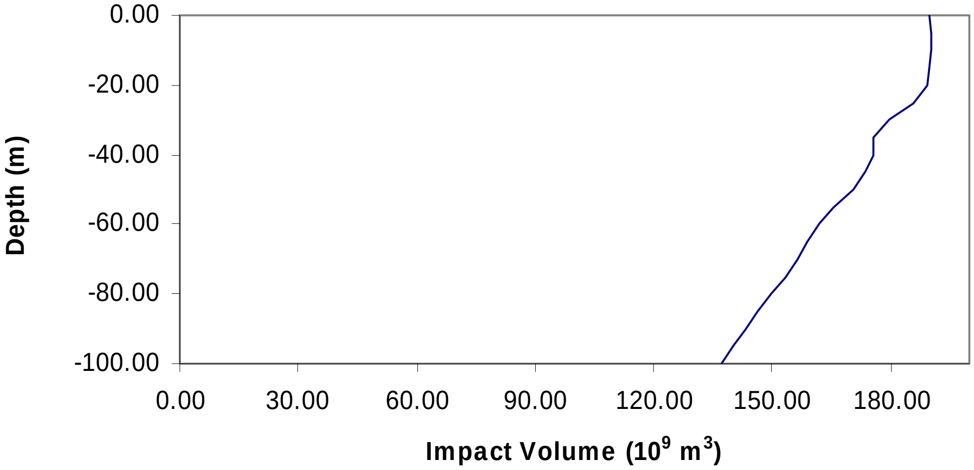


Figure 6-26: Example of an Impact Volume Vector.

6.21 Exposures/Takes

This section demonstrates how three-dimensional animal densities (animal density vectors) and the per-run impact volumes can be used together to calculate expected harassments. Also, it defines the animal densities and their depth distributions for the NAVSEA NUWC Keyport Range Complex, and shows how they are used to create animal density vectors.

6.21.1 Take estimates

The following sperm whale example demonstrates the methodology used to create a three-dimensional density by merging the area densities with the depth distributions. In Quinault, the sperm whale surface density is 0.0011 whales per square kilometer. From the depth distribution report, "depth distribution for sperm whales based on information in the Amano, Yoshiaka (2003) paper is: 31% in <10 m, 8% in 10-200 m, 9% in 201-400 m, 9% in 401-600 m, 9% in 601-800 m and 34% in >800 m." So the sperm whale density at 0-10 m is 0.0011*0.31/0.01 = 0.0341 per cubic km, at 10-200 m is 0.0011*0.08/0.190 = 0.0004632 per cubic km, and so forth.

In general, the impact volume vector samples depth in finer detail than given by the depth distribution data. When this is the case, the densities are apportioned uniformly over the appropriate intervals. For example, suppose the impact volume vector provides volumes for the intervals 0-2 meters, 2-10 meters, and 10-50 meters. Then for the depth-distributed densities discussed in the preceding paragraph,

- 0.0341 whales per cubic km is used for 0-2 meters,
- 0.0341 whales per cubic km is used for the 2-10 meters, and
- 0.0004632 whales per square km is used for the 10-50 meters.

Once depth-varying, three-dimensional densities are specified for each species type, with the same depth intervals and the ensonified volume vector, the density calculations are finished. The expected number of ensonified animals within each depth interval is the ensonified volume at that interval multiplied by the volume density at that interval and this can be obtained as the dot product of the ensonified volume and animal density vectors.

6.21.2 Additional Modeling Considerations in a General Modeling Scenario

When modeling the effect of sound projectors in the water, the ideal task presents modelers with complete *a priori* knowledge of the location of the source(s) and transmission patterns during the times of interest. In these cases, calculation inputs include the details of source path, proximity of shoreline, high-resolution density estimates, and other details of the scenario. However, in the NAVSEA NUWC Keyport Range Complex, there are sound-producing events for which the source locations and transmission patterns are unknown, but still require analysis to predict effects. For these cases, a more general modeling approach is required: "We will be operating somewhere in this large area for X minutes. What are the potential effects on average?"

Modeling these general scenarios requires a statistical approach to incorporate the scenario nuances into harassment calculations. For example, one may ask: "If an animal receives 130 dB SPL when the source passes at closest point of approach (CPA) on Tuesday morning, how do we know it doesn't receive a higher level on Tuesday afternoon?" This question cannot be answered without knowing the path of the source (and several other facts). Because the path of the source is unknown, the number of an individual's re-exposures cannot be calculated directly. But it can, on average, be accounted for by making appropriate assumptions.

The following table lists unknowns created by uncertainty about the specifics of a future proposed action, the portion of the calculation to which they are relevant, and the assumption that allows the effect to be computed without the detailed information:

Table 6-19: Unknowns and Assumptions

Unknowns	Relevance	Assumption
Path of source(esp. with respect to animals)	Ambiguity of multiple exposures, Local population: upper bound of harassments	Most conservative case: sources can be anywhere within range
Source locations	Ambiguity of multiple exposures, land shadow	Equal distribution of action in each range
Direction of acoustic transmission	Land shadow	Equal probability of pointing any direction

The following sections discuss two topics that require action details, and describe how the modeling calculations used the general knowledge and assumptions to overcome the future-action uncertainty with respect to re-exposure of animals, and land shadow.

Multiple Exposures in General Modeling Scenario

Consider the following hypothetical scenario. A box is painted on the surface of a well-studied ocean environment with well-known propagation. An acoustic-source and 100 whales are inserted into that box and a curtain is drawn. What will happen? This is the general scenario. The details of what will happen behind the curtain are unknown, but the existing knowledge, and general assumptions, can allow for a general calculation of average affects.

For the first period of time, the source is traveling in a straight line and pinging at a given rate. In this time, it is known how many animals, on average, receive their max SPLs from each ping. As long as the source travels in a straight line, this calculation is valid. However, after an undetermined amount of time, the source will change course to a new and unknown heading.

If the source changes direction 180 degrees and travels back through the same swath of water, all the animals the source passes at closest point of approach (CPA) before the next course change have already been exposed to what will be their maximum SPL, so the population is not "fresh." If the direction does not change, only new animals will receive what will be their maximum SPL from that source (though most have received sound from it), so the population is completely "fresh." Most source headings lead to a population of a mixed "freshness," varying by course direction. Since the route and position of the source over time are unknown, the freshness of the population at CPA with the source is unknown. This ambiguity continues through the remainder of the exercise.

What is known? The source and, in general, the animals remain in the vicinity of the range. Thus, if the farthest range to a possible effect from the source is X km, no animals farther than X km outside of the range site can be harassed. The intersection of this area with a given animal's habitat multiplied by the density of that animal in its habitat represents the maximum number of animals that can be harassed by activity in that range site, which shall be defined as "the local population." Two details: first, this maximum should be adjusted down if a risk function is being used, because not 100% of animals within X km of the range site border will be harassed. Second, it should be adjusted up to account for animal motion in and out of the area. In the Keyport and Dabob ranges, land masses interfere with propagating sound before it can travel a long distance. In those areas, the initial area of effect is small, because land constrains sound propagation, so the number of animals that could swim into the area drive the upper bound of harassments. In Quinault, however, the range alternatives are large, and not impeded by land, so in Quinault the animal motion does not have as great an effect on the upper bound of harassments.

The ambiguity of population freshness throughout the exercise means that multiple exposures cannot be calculated for any individual animal. It must be dealt with generally at the population level.

Solution to the Ambiguity of Multiple Exposures in the General Modeling Scenario

At any given time, each member of the population has received a maximum SPL (possibly zero) that indicates the probability of harassment in the exercise. This probability indicates the contribution of that individual to the expected value of the number of harassments. For example, if an animal receives a level that indicates 50% probability of harassment, it contributes 0.5 to the sum of the expected number of harassments. If it is passed later with a higher level that indicates a 70% chance of harassment, its contribution increases to 0.7. If two animals receive a level that indicates 50% probability of harassment, they together contribute 1 to the sum of the expected number of harassments. That is, we statistically expect exactly one of them to be harassed. Let the expected value of harassments at a given time be defined as "the harassed population" and the difference between the local population (as defined above) and the harassed population be defined as "the unharassed population." As the exercise progresses, the harassed population will never decrease and the unharassed population will never increase.

The unharassed population represents the number of animals statistically "available" for harassment. Since we do not know where the source is, or where these animals are, we assume an average (uniform) distribution of the unharassed population over the area of interest. The densities of unharassed animals are lower than the total population density because some animals in the local population are in the harassed population.

Density relates linearly to expected harassments. If action A in an area with a density of 2 animals per square kilometer produces 100 expected harassments, then action A in an area with 1 animal per square kilometer produces 50 expected harassments. The modeling produces the number of expected harassments per ping starting with 100% of the population unharassed. The next ping will produce slightly fewer harassments because the pool of unharassed animals is slightly less.

For example, consider the case where 1 animal is harassed per ping when the local population is 100, 100% of which are initially unharassed. After the first ping, 99 animals are unharassed, so the number of animals harassed during the second ping are

$$10\left(\frac{99}{100}\right) = 1(.99) = 0.99 \text{ animals}$$

and so on for the subsequent pings.

Mathematics

A closed form function for this process can be derived as follows.

Define $P_n =$ unharassed population after ping n

Define $H =$ number of animals harassed in a ping with 100% unharassed population

$$P_0 = \text{local population}$$

$$P_1 = P_0 - H$$

$$P_2 = P_1 - H\left(\frac{P_1}{P_0}\right)$$

$$\ldots$$

$$P_n = P_{n-1} - H\left(\frac{P_{n-1}}{P_0}\right)$$

Therefore,

$$P_n = P_{n-1}\left(1-\left(\frac{H}{P_0}\right)\right) = P_{n-2}\left(1-\left(\frac{H}{P_0}\right)\right)^2 = \ldots = P_0\left(1-\left(\frac{H}{P_0}\right)\right)^n$$

Thus, the total number of harassments depends on the per-ping harassment rate in an unharassed population, the local population size, and the number of operation hours.

Local Population: Upper Bound on Harassments

As discussed above, Navy planners have confined period of acoustic use to RDT&E areas. The size of the harassed population of animals for an action depends on animal re-exposure, so uncertainty about the precise source path creates variability in the "harassable" population. Confinement of active acoustics use to an operating area allows modelers to compute an upper bound, or worst case, for the number of harassments with respect to location uncertainty. This is done by assuming that there is an active acoustic source transmitting from each point in the confined area throughout the action length.

NMFS has defined a twenty-four hour "refresh rate," or amount of time in which an individual can be harassed no more than once. Navy has determined that, in a twenty-four hour period, all sonar operations in the NAVSEA NUWC Keyport Range Complex transmit for a subset of that time defined in Table 6-20.

Table 6-20: Duration of Sonar Use During 24-hour Period

System	Longest continuous interval
S1	4 hours
S2	2 hours
S3	2 hours
S4	2 hours
S5	20 minutes
S6	10 minutes
S7	10 minutes
S8	10 minutes

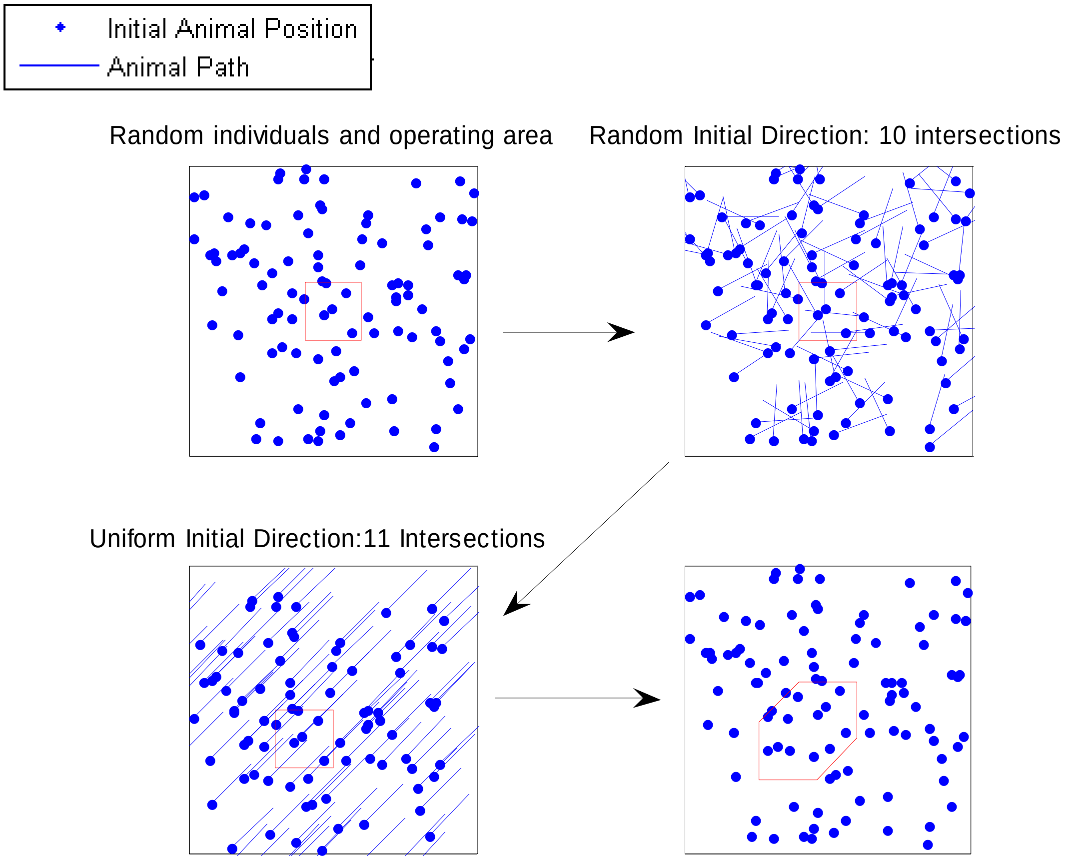
Creating the most conservative source position by assuming that a sonar transmits from each point on the range simultaneously can produce an upper bound on harassments for a single ping, but animal motion over the period in the above table can bring animals into range that otherwise would be out of the harassable population.

Animal Motion Expansion

Though animals often change course to swim in different directions, straight-line animal motion would bring the more animals into the harassment area than a "random walk" motion model. Since precise and accurate animal motion models exist more as speculation than documented fact and because the modeling requires an undisputable upper bound, calculation of the upper bound for Keyport Range Complex modeling areas uses a straight-line animal motion assumption. This is a conservative assumption.

For a circular area, the straight-line motion with initial random direction assumption produces an identical result to the initial fixed direction. Since the ranges are non-circular polygons, choosing the initial fixed direction as perpendicular to the longest diagonal produces greater results than the initial random direction. Thus, the product of the longest diagonal and the distance the animals move in the period of interest gives an overestimate of the expansion in range modeling areas due to animal motion. The NAVSEA NUWC Keyport Range Complex extensions use this overestimate for the animal-motion expansion.

The figure below (Figure 6-27) illustrates an example that illustrates the overestimation, which occurs during the second arrow:



An individual inside the adjusted box will be in the original box sometime during the period of interest.

Figure 6-27: Process of Overestimating Individuals Present in Area at Any Time.

Risk Function Expansion

The expanded area contains the number of animals that will enter the range over the period of interest. However, an upper bound on harassments must also include animals outside the area that would be affected by a source transmitting from the area's edge. A gross overestimation could simply include all area with levels greater than the risk function basement. In the case of Quinault, this would include all area within approximately 65 km from the edge of the adjusted box. This basic method would give a crude and inaccurately high upper bound, since only a fraction of the population is affected in much of that area. A more refined upper bound on harassments can be found by maintaining the assumption that a sonar is transmitting from each point in the adjusted box and calculating the expected ensonified area.

The expected lateral range from the edge of a polygon to the cutoff range can be expressed as,

$$\int_{0}^{L^{-1}(120\,dB)} D(L(r))dr$$

where D is the risk function with domain in level and range in probability, L is the SPL function with domain in range and range in level, and r is the range from the sonar operating area.

At the corners of the polygon, additional area can be expressed as

$$\frac{[\pi-\theta]\displaystyle\int_{0}^{L^{-1}(120\,dB)} D(L(r))r\,dr}{2\pi}$$

with D, L, and r as above, and θ the inner angle of the polygon corner, in radians.

For the risk function and transmission loss of the NAVSEA NUWC Keyport Range Complex, this method adds an area equivalent by expanding the boundaries of the adjusted box by four kilometers. The resulting shape, the adjusted box with a boundary expansion of 4 km, does not possess special meaning for the problem. But the number of individuals contained by that shape, as demonstrated above, is an overestimate of the number of harassments that would occur if sonars transmitted continuously from each point in the range over the exercise length, an upper bound on harassments for that operation.

Figure 6-28 illustrates the growth of area for the sample case above. The shapes of the boxes are unimportant. The area after the final expansion, though, gives an upper bound on the "harassable," or unharassed population.

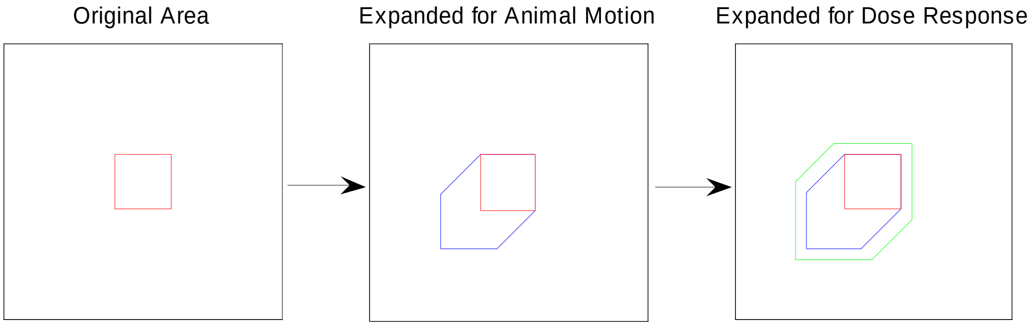


Figure 6-28: Process of Expanding Area to Create Upper Bound of Harassments

Example Case

Consider a sample case from the Quinault range with Kalaloch extension: for the most powerful source, S6, the expected summer rate of harassment for Pacific whitesided dolphins is approximately 0.58743378 harassments per ping. The exercise will transmit sonar pings for ten minutes in a 24 hour period, as given in the action table above, with 2 pings per minute, a total of 2*10=20 pings in a 24 hour period.

The Quinault range with Kalaloch extension has an area of approximately 9033 square kilometers and a largest side of 300 km. Adjusting this with straight-line (upper bound) animal motion of 5.5 kilometers per hour for 10 minutes, or 0.167 hours, animal motion adds 300*5.5*0.167= 255 square kilometers to the area. Using the risk function to calculate the expected range outside the SOA adds another 2475 square kilometers, bringing the total upper-bound of the affected area to 11,733 square km.

For this analysis, whitesided dolphins have an average density of 0.1929 animals per square kilometer in the Quinault range with Kalaloch extension, so the upper bound number of whitesided dolphins that can be affected by S5 activity in the Quinault Range with Kalaloch Extension during a 24 hour period is 11,733 *0.1929 = 2263.3 dolphins.

In the first ping, 0.58743378 whitesided dolphins will be harassed. With the second ping,

$0.58743378 \quad \left(\frac{2263.3 - 0.58743378}{2263.3} \right) = 0.5873$ whitesided dolphins will be harassed. Using the formula derived above, after 10 minutes of continuous operation, the remaining **unharassed** population is

$$P_{240} = P_0 \left(1 - \left(\frac{h}{P_0} \right) \right)^{20} = 2263.3 \left(1 - \left(\frac{.587433781}{2263.3} \right) \right)^{20} \approx 2251.6$$

So the **harassed** population will be 2263.3-2251.6=11.7 animals.

Contrast this with linear accumulation of harassments without consideration of the local population and the dilution of the unharassed population:

Harassments = 0.58743378 *20=11.748

Land Shadow

The risk function considers harassment possible if an animal receives 120 dB sound pressure level, or above. In the open ocean of the Quinault range, this can occur as far away as 65 km, so over a large "effect" area, sonar sound could, but does not necessarily, harass an animal. The harassment calculations for a general modeling case must assume that this effect area covers only water fully populated with animals, but in some portions of the NAVSEA NUWC Keyport Range Complex, particularly the inshore ranges, land partially encroaches on the area, obstructing sound propagation.

As discussed in the introduction of "Additional Modeling Considerations..." Navy planners do not know the exact location and transmission direction of the sonars at future times. These factors however, completely determine the interference of the land with the sound, or "land shadow," so a general modeling approach does not have enough information to compute the land shadow effects directly. However, modelers can predict the reduction in harassments at any point due to land shadow for different pointing directions and use expected probability distribution of activity to calculate the average land shadow for operations in each range.

For the ranges, in each alternative, the land shadow is computed over a dense grid in each operations area. The grid for QUTR is shown in Figure 6-29. The dense grid is shown by the near-continuous green dots. For illustrative purposes, every 25th point is shown as a red cross.

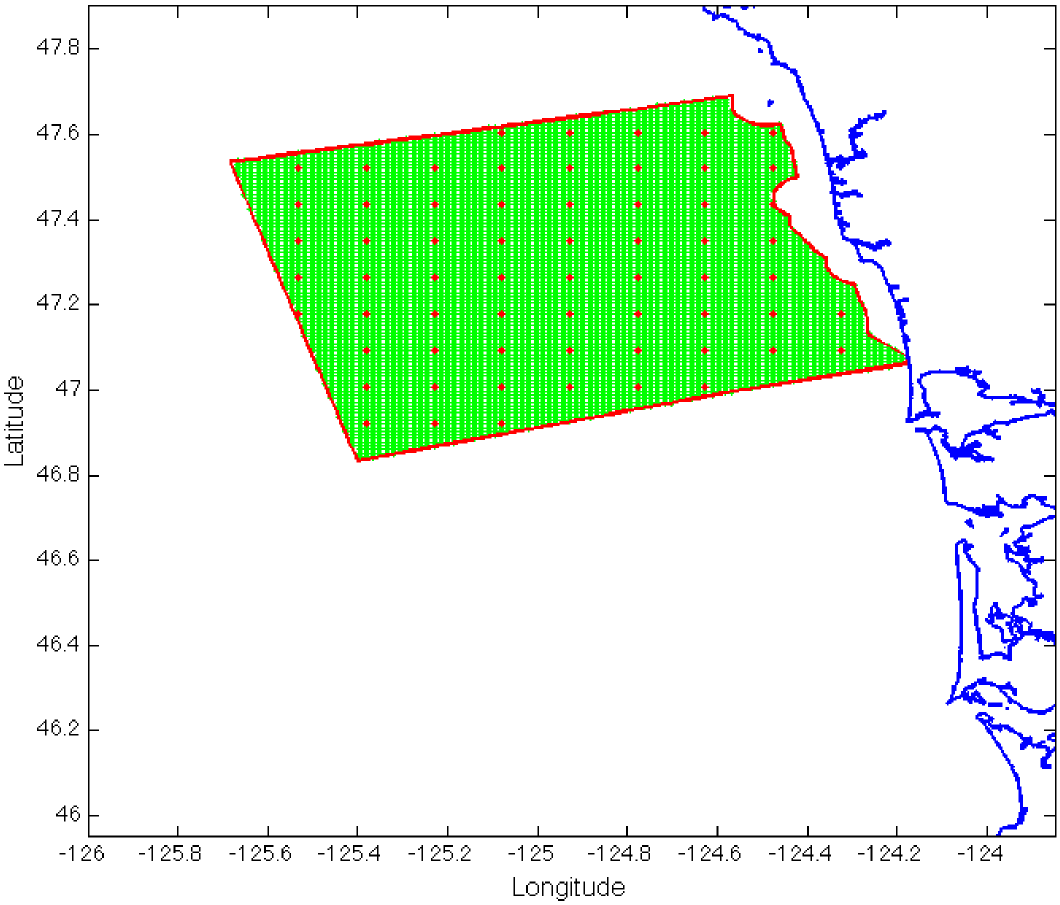


Figure 6-29: Grid for an extenderd QUTR with Ocean City AlternativeRange.

For each grid point, the land shadow is computed by combining the distance to land and the azimuth coverage. The process finds all of the points within 65 km of the gridpoint, as shown in Figure 6-30, in an example from the extended Quinault range Ocean City alternative. The red X is one grid point, with the green circle corresponding to a radius of 65 km from the grid point.

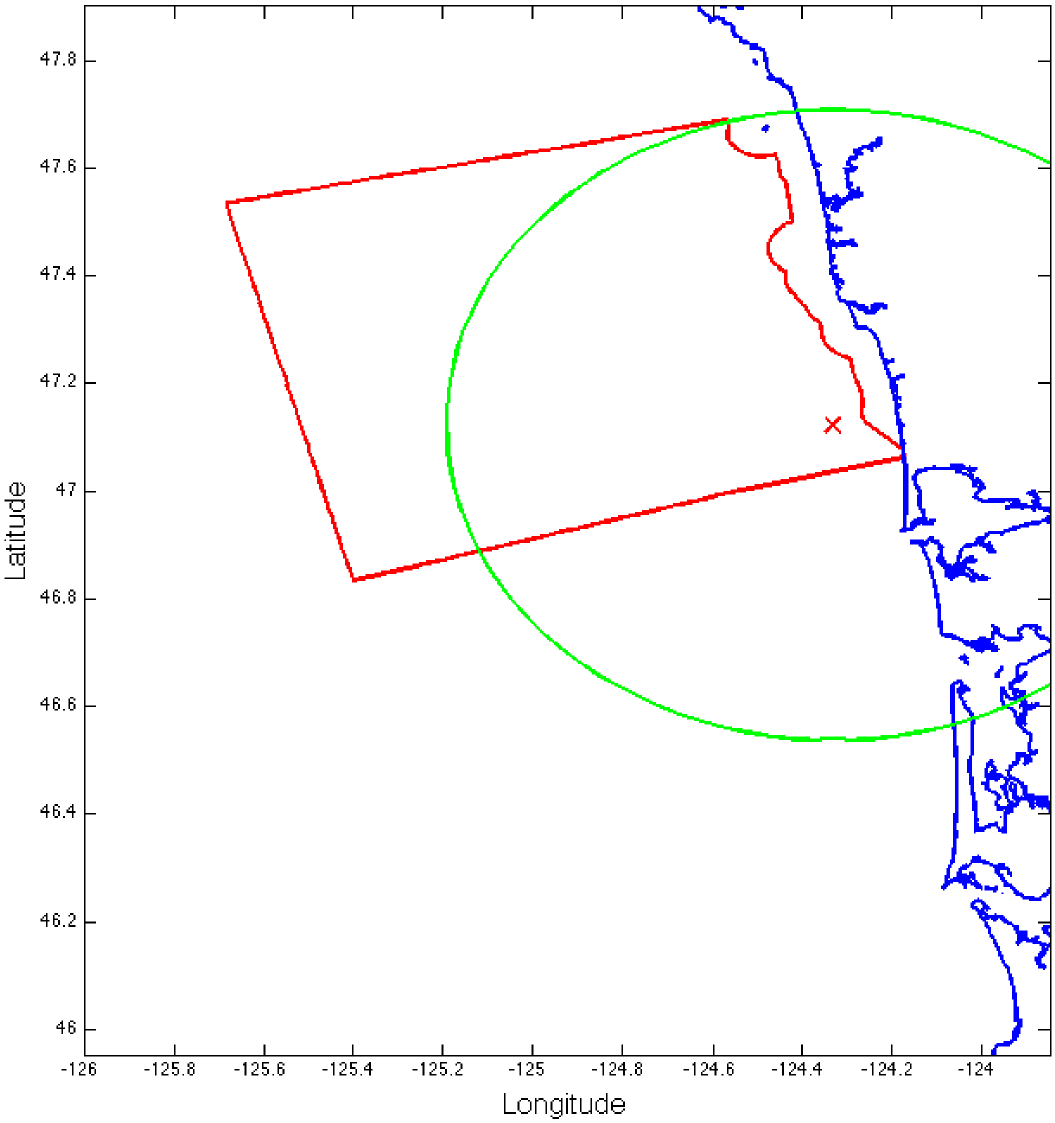


Figure 6-30: The red box is the operations area.

For each of the coastal points that are within 65 km of the grid, the azimuth and distance is computed. In the computation, only the minimum range at each azimuth is computed. The minimum range compared with azimuth for the sample point is shown in Figure 6-31.

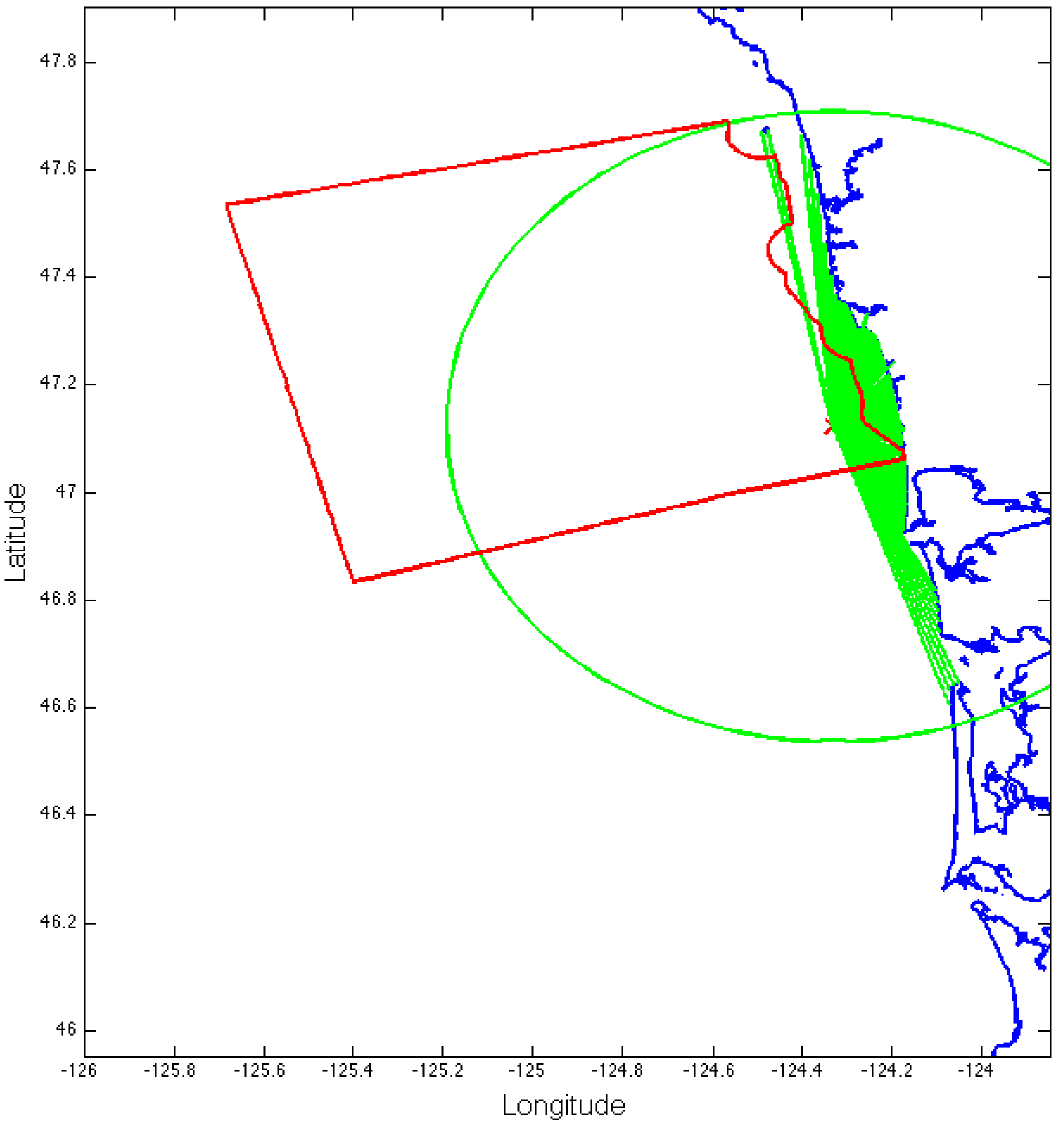


Figure 6-31: The nearest point at each azimuth (with 1° spacing) to a sample grid point (red X) is shown by the green lines.

Now, the average of the distances to shore, along with the angular profile of land is computed (by summing the unique azimuths that intersect the coast) for each grid point. The values are then used to compute the land shadow for the grid points.

Computing the Land Shadow Effect at Each Grid Point

The effect of land shadow is computed by determining the levels, and thus the distances from the sources, that the harassments occur. Table 6-21 gives a mathematical extrapolation of the distances and levels at which harassments occur, with average propagation in the NAVSEA NUWC Keyport Range Complex.

Table 6-21: Behavioral Harassments at each Received Level Band from S6

Received Level (dB SPL)	Distance at which Levels Occur in Range Site	Percent of Harassments Occurring at Given Levels
Below 150	4 km - 12 km	< 1 %
150>Level>160	2.3 km – 4 km	10 %
160>Level>170	1.0 km – 2.3 km	35 %
170>Level>180	400 m – 1000 m	33 %
180>Level>190	140 m – 400 m	15 %
190>Level>200	45 m – 140 m	6 %
Above 200	0 m – 45 m	<1 %

With the data used to produce the previous figure, the average effect reduction across season for a sound path blocked by land can be calculated. For example, for S6, since approximately 86% of harassments occur within 2 kilometers of the source, a sound path blocked by land at 2 kilometers will, on average, cause approximately 86% the effect of an unblocked path (Figure 6-33).

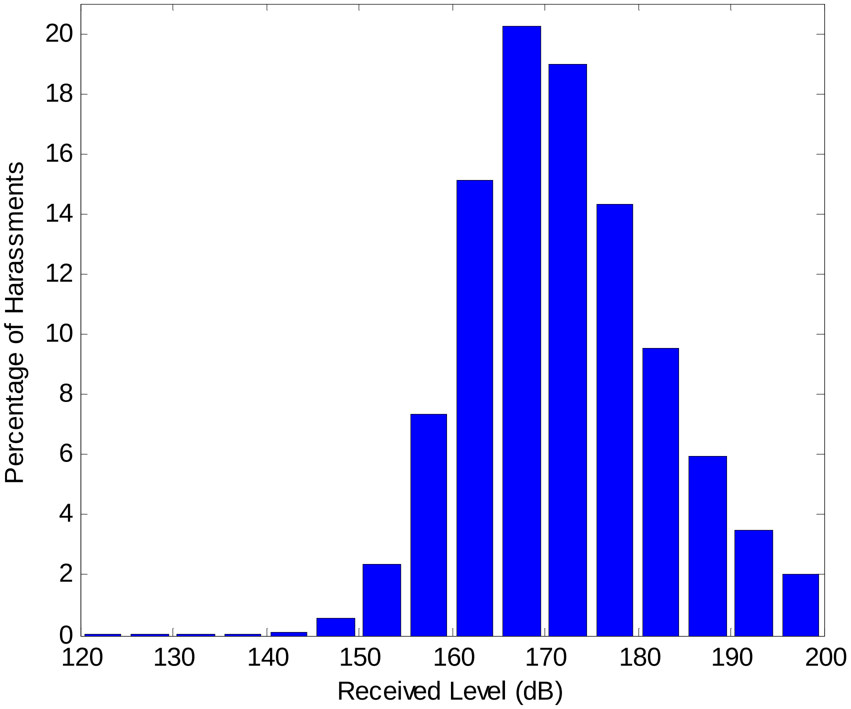


Figure 6-32: The percentage of behavioral harassments for every 5 degree band of received level from the S6

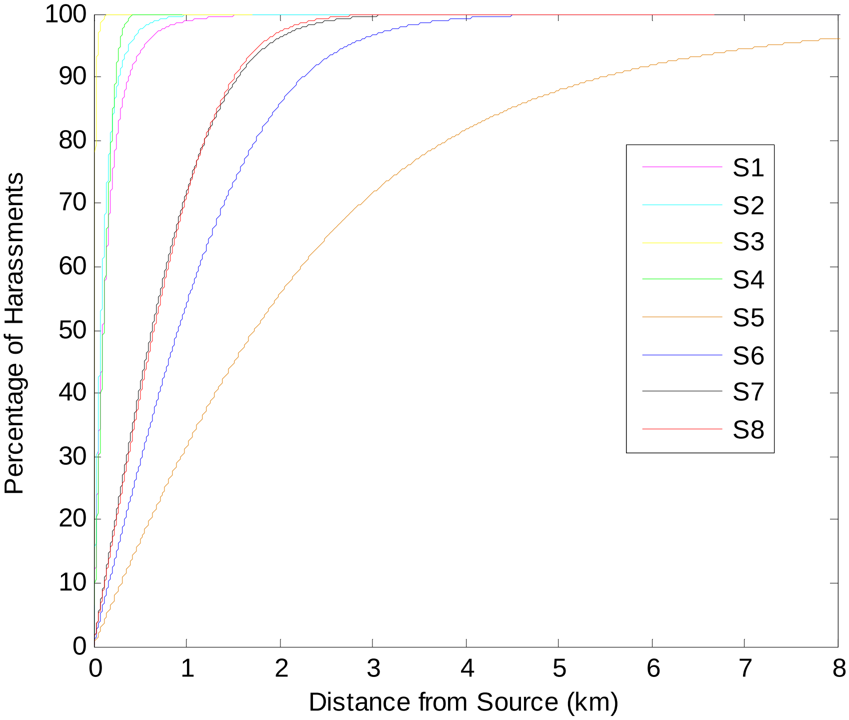


Figure 6-33: Average Percentage of Harassments Occurring Within a Given Distance

As described above, the mapping process determines the angular profile of and distance to the coastline(s) from each grid point. The distance, then, determines the reduction due to land shadow when the sonar is pointed in that direction. The angular profile, then, determines the probability that the sonar is pointed at the coast.

Define θ_n = angular profile of coastline at point n in radians

Define r_n = mean distance to shoreline

Define A(r) = average effect adjustment factor for sound blocked at distance r

The land shadow at point n can be approximated by $A(r_n)\theta_n/(2\pi)$ and is presented in Table 6-22.The average land shadow for each existing and proposed range is calculated by averaging the average land shadow at each point. The average land shadow factor for the range will modify the per-ping harassment.

Table 6-22. TL Depth and Range Sampling Parameters by Sonar Type

	S1	S2	S3	S4	S5	S6	S7	S8
DBRC with Northern Extension	0.9978	0.9991	1.0000	0.9995	0.8171	0.9392	0.9698	0.9709
DBRC with Southern Extension	0.9978	0.9991	1.0000	0.9995	0.8166	0.9388	0.9695	0.9706
Extended QUTR With Kalaloch	1.0000	1.0000	1.0000	1.0000	0.9997	1.0000	1.0000	1.0000
Existing DBRC	0.9980	0.9992	1.0000	0.9996	0.8187	0.9442	0.9729	0.9739
Existing Keyport	0.9965	0.9984	1.0000	0.9991	0.7799	0.9173	0.9559	0.9569
Extended Keyport	0.9972	0.9988	1.0000	0.9995	0.7754	0.9195	0.9588	0.9599
Extended QUTR with Ocean City	1.0000	1.0000	1.0000	1.0000	0.9997	1.0000	1.0000	1.0000
Extended QUTR with PACBEACH	1.0000	1.0000	1.0000	1.0000	0.9997	1.0000	1.0000	1.0000
Extisting QUTR	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000	1.0000	1.0000

6.21.3 Estimated Effects on Marine Mammals

This Section is a summary of potential acoustic energy exposures to marine mammals. No Level A exposures are identified. Table 6-23, 6-24, and 6-25 present the total number of Level B harassment. Only species expected to be present in the NAVSEA NUWC Keyport Range Complex were evaluated for this LOA request.

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 used in the model, and that the model results must be interpreted within the context of a given species' ecology. When reviewing the acoustic effects modeling results, it is also important to understand that the estimates of marine mammal sound exposures are presented without consideration of standard mitigation operating procedures or the fact that there have been no confirmed acoustic effects on any marine species in previous NAVSEA NUWC Keyport Range Complex exercises or from any other mid- and high-frequency active sonar RDT&E activities within the NAVSEA NUWC Keyport Range Complex.

All Level B harassment would be short term and temporary in nature. In addition, the short-term non-injurious exposures predicted to cause TTS or temporary behavioral disruptions are considered Level B harassment in this LOA even though it is highly unlikely that the disturbance would be to a point where behavioral patterns are abandoned or significantly altered. The modeling for NAVSEA NUWC Keyport Range Complex analyzed the potential interaction of mid- and high-frequency active acoustic sources with marine mammals that occur in the NAVSEA NUWC Keyport Range Complex.

The annual estimated number of exposures from acoustic sources are given for each species. The modeled exposure is the probability of a response that NMFS would classify as harassment under the MMPA. These exposures are calculated for all activities modeled and represent the total exposures per year and are not based on a per day basis.

Acoustic Exposure Summary

This LOA utilizes the following methods for predicting the number of potential effects to marine mammals for the NAVSEA NUWC Keyport Range Complex. EFD was originally used to predict all physiological and behavioral effects, based on best science at the time. Subsequently, as science evolved the risk function methodology was developed to predict behavioral effects. As new science and modeling predictions are matured the eventual analysis methodology will be used. This accounts for Level B behavioral and physiological effects for all three range sites for all marine mammals. Those species with densities greater than zero, including season densities, were analyzed for potential impacts from acoustic sources. Therefore, only those species with potential exposures are listed in the tables below.

The modeling for acoustic sources using the risk function methodology and implementation of ROP predicts 15,130 annual acoustic exposures that result in Level B harassment and 2,026 annual exposures of pinnipeds that exceed the TTS threshold for Level B Harassment under that criteria. The model predicts 0 annual exposures that exceed the PTS threshold (Level A Harassment). The summary of modeled mid- and high-frequency acoustic source exposure harassment numbers by species are presented in Tables 6-23 through 6-26 and represent potential harassment after implementation of ROP. Numbers provided in parenthesis in Tables 6-23 through 6-25 indicate estimated exposures without implementation of ROP.

Table 6-23: Estimated Annual MMPA Level B Exposures For Inland Water - Keyport Range Site

	EL TTS (Level B) Exposures1	Risk Function Sub-TTS Behavioral Exposures
Harbor Seal	41 (41)	109 (41)
Total Level B Exposures (by criteria method)	41	109

Table 6-24: Estimated Annual MMPA Level B Exposures For Inland Water - DBRC Site

	EL TTS (Level B) Exposures	Risk Function Sub-TTS Behavioral Exposures
Killer Whale	0 (1)	0 (54)
California Sea Lion	0 (0)	109 (109)
Harbor Seal	1,998 (1,998)	3,320 (3,320)
Total Level B Exposures (by criteria method)	1,998	3,429

Table 6-25: Estimated Annual MMPA Level B Exposures for Open Ocean - QUTR Site

	EL TTS (Level B) Exposures	Risk Function Sub-TTS Behavioral Exposures
Endangered or Threatened Species		
Blue Whale	0 (0)	0 (0)
Fin Whale	0 (0)	0 (1)
Humpback Whale	0 (0)	0 (3)
Sei Whale	0 (0)	0 (1)
Sperm Whale	0 (0)	0 (1)
Killer Whale	0 (0)	0 (1)
Steller Sea Lion	0 (0)	0 (3)
Non-ESA Listed Species		
Minke Whale	0 (0)	0 (0)
Gray Whale	0 (0)	0 (1)
Dwarf and Pygmy Sperm Whale	0 (0)	0 (1)
Baird's Beaked Whale	0 (0)	0 (1)
Mesoplodons	0 (0)	0 (1)
Risso's Dolphin	0 (0)	0 (1)
Pacific White Sided Dolphin	0 (0)	0 (27)
Short Beaked Common Dolphin	0 (0)	0 (1)
Striped Dolphin	0 (0)	0 (0)
Northern Right Whale Dolphin	0 (0)	0 (16)
Dall's Porpoise	0 (0)	0 (56)
Harbor Porpoise	0 (1)	11,282 (11,282)
Northern Fur Seal	0 (0)	44 (44)
California Sea Lion	0 (0)	5 (5)
Northern Elephant Seal	0 (0)	14 (14)
Harbor Seal	23 (23)	78 (78)
Total Level B Exposures (by criteria method)	23	11,423

Table 6-26: Combined Estimated Annual MMPA Level B Exposures (EL and Risk Function) for Proposed Annual RDT&E Activities Operations at All Sites after Implementation of ROP

	EL TTS (Level B) Exposures	Risk Function Sub-TTS Behavioral Exposures
Endangered or Threatened Species		
Blue Whale	0	0
Fin Whale	0	0
Humpback Whale	0	0
Sei Whale	0	0
Sperm Whale	0	0
Killer Whale	0	0
Steller Sea Lion	0	0
Non-ESA Listed Species		
Minke Whale	0	0
Gray Whale	0	0
Dwarf and Pygmy Sperm Whale	0	0
Baird's Beaked Whale	0	0
Mesoplodons	0	0
Risso's Dolphin	0	0
Pacific White Sided Dolphin	0	0
Short Beaked Common Dolphin	0	0
Striped Dolphin	0	0
Northern Right Whale Dolphin	0	0
Dall's Porpoise	0	0
Harbor Porpoise	0	11,282
Northern Fur Seal	0	44
California Sea Lion	0	114
Northern Elephant Seal	0	14
Harbor Seal	2,062	3,507
Total Level B Exposures (by criteria method)	2,062	14,961

It is highly unlikely that a marine mammal would experience any long-term effects because the large NAVSEA NUWC Keyport Range Complex test areas makes individual mammals' repeated and/or prolonged exposures to high-level sonar signals unlikely. Specifically, mid- and high-frequency acoustic sources have limited marine mammal exposure ranges and relatively high platform speeds. There are no exposures that exceed the PTS threshold and result in Level A harassment from sonar. 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.

When reviewing the acoustic exposure modeling results, it is also important to understand that the estimates of marine mammal sound exposures are presented with consideration of standard protective measure operating procedures. Section 11.1 presents details of ROP currently used for RDT&E activities including detection of marine mammals and power down procedures if marine mammals are detected 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.

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 Level B harassment. This approach is overestimating because there is no established scientific correlation between acoustic sources use and long term abandonment or significant alteration of behavioral patterns in marine mammals.

Because of the time delay between pings, 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.

6.21.4 Assessment of Marine Mammal Response to Acoustic Exposures

Section 6.2.1 presented the concept that potential effects of sound include both physiological effects and behavioral effects. Section 6.4 through 6.16 provide 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 acoustic sources to be used in the NAVSEA NUWC Keyport Range Complex. 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. These data are described in detail in Schlundt et al. (2000) and Finneran and Schlundt (2004). These data, because they are based on controlled, tonal sound exposures within the mid-frequency 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.
- Overlap of TTS and risk function.

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.

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- and high-frequency acoustic sources 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.

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 NAVSEA NUWC Keyport Range Complex 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.

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 NAVSEA NUWC Keyport Range Complex (Sections 4.1 and 4.2). 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.

6.21.5 Estimated Effects on ESA Species

The endangered species that may be affected as a result of implementation of the NAVSEA NUWC Keyport Range Complex activities include the blue whale, fin whale, humpback whale, northern Pacific right whale, sei whale, sperm whale, resident killer whale, and Steller sea lion.

Blue Whale (*Balaenoptera musculus*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, no blue whales are predicted to be behaviorally harassed annually from testing and training in the NAVSEA NUWC Keyport Range Complex (Table 6-26).

Modeling indicates 0 exposures to accumulated acoustic energy between of 195 dB and 215 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. Modeling indicates that no blue whales would be exposed to accumulated acoustic energy at or above 215 dB re 1 μPa^2-s, which is the threshold indicative of onset PTS.

Given the large size (up to 80 ft. [24 m]) of individual blue whales, pronounced vertical blow, and typically travelling in pairs (Leatherwood et al., 1982) and (probability of trackline detection = 0.92 in Beaufort Sea States of 5 or less; Forney 2007), it is very likely that lookouts would detect a group of blue whales at the surface. Additionally, ROP call for continuous visual observation during activities with mid- and high-frequency acoustic sources; therefore, blue whales that migrate into the operating area would be detected by visual observers. Implementation of ROP and probability of detecting a blue whale reduces the likelihood of exposure, such that effects would be discountable.

Based on the model results, behavioral patterns, acoustic abilities of blue whales, results of past RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- and high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to blue whales.

Fin Whale (*Balaenoptera physalus*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of fin whales predicted to be behaviorally harassed from testing and training in the NAVSEA NUWC Keyport Range is zero (Table 6-26).

Modeling indicates no exposures to accumulated acoustic energy between of 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling indicates no exposures for fin whales to accumulated acoustic energy above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

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 = 0.92 in Beaufort Sea States of 5 or less; Forney 2007) it is very likely that lookouts would detect a group of fin whales at the surface. Additionally, ROP call for continuous visual observation during activities with mid- and high-frequency acoustic sources; therefore, fin whales in the vicinity of activities would be detected by visual observers. Implementation of ROP 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- or high-frequency acoustic sources, 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 Range Complex 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 RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- and high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would likely not result in any death or injury to fin whales, but some Level B behavioral harassment may occur.

An ESA consultation is ongoing, and includes the finding that the proposed RDT&E activities may affect fin whales. Should consultation under the ESA conclude that the estimated exposures of fin whales can be avoided via ROP 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 does not request authorization for the harassment of fin whales by Level B harassment from potential exposure to acoustic sources.

Humpback Whale (*Megaptera novaeangliae*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of humpback whales predicted to be behaviorally harassed from RDT&E activities after implemtation of ROP in the NAVSEA NUWC Keyport Range Complex is 0 (Table 6-26).

Modeling indicates no exposures to accumulated acoustic energy between of 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling indicates no exposures for humpback whales to accumulated acoustic energy above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

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, ROP call for continuous visual observation during activities with mid- and high-frequency acoustic sources; therefore, humpback whales that are present in the vicinity of RDT&E 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). Based on this information, if they do not hear these sounds, they are not likely to respond physiologically or behaviorally to those received levels, such that effects would be insignificant. A single study suggested that humpback whales responded to mid- and high-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- and high-frequency acoustic sources). 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 responses 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). 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 RDT&E activities, and the implementation of ROP presented in section 11.1 for mid-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not likely result in any death or injury to humpback whales. Modeling does indicate the potential for Level B harassment, indicating the proposed RDT&E activities may affect humpback whales.

An ESA consultation is ongoing, and includes the finding that the proposed RDT&E activities 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 does not request authorization for the harassment of humpback whales by either Level B or Level A harassment from potential exposure to acoustic sources.

North Pacific Right Whale (*Eubalaena japonica*)

There is no density information available for North Pacific right whales in Oregon/Washington waters since they have not been seen during survey. Given they are so few in number, it is unlikely that NAVSEA NUWC Keyport Range Complex mid- and high-frequency RDT&E activities will result in the exposure of any right whales to accumulated acoustic energy in excess of any energy flux threshold or a SPL in excess of 145 dB.

Given their large size (up to 56 ft [17m]) of individual North Pacific right whales (Leatherwood et al. 1982), surface behavior (e.g., breaching), pronounced blow, and mean group size 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 North Pacific right whales at the surface. Additionally, mitigation measures call for continuous visual observation during activities with active sonar; therefore, large whales that are present in the operating area would be detected by visual observers. Implementation of mitigation measures and probability of detecting a large North Pacific right whale reduces the likelihood of exposure, such that effects would be discountable.

In the unlikely event that North Pacific right whales are exposed to mid- or high-frequency acoustic sources, the information available on North Pacific right suggests that they may hear the lower range of mid-frequency (1 kHz–10 kHz) sounds (Richardson et al., 1995; Ketten 1997). There are no audiograms for baleen whales but they are estimated to hear from 15 Hz to 20 kHz with good sensitivity from 20 Hz to 2 kHz (Ketten, 1998).

Mid- and high-frequency acoustic sources may temporarily mask some sounds in the range of North Pacific right whale hearing and may also cause a temporary behavioral response (i.e., diving or swimming away from the sound source). Even though any undetected North Pacific right whales transiting the NAVSEA NUWC Keyport Range Complex may exhibit a reaction when initially exposed to active acoustic energy, these 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 North Pacific right whales, results of past RDT&E, and the implementation of ROP presented in section 11.1 for sonar, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not likely result in any death or injury to North Pacific right whales.

Sei Whale (*Balaenoptera borealis*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of sei whales predicted to be behaviorally harassed from RDT&E activities after implementation of ROP in the NAVSEA NUWC Keyport Range Complex is 0 (Table 6-26).

Modeling indicates no exposures to accumulated acoustic energy between of 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling predicts no exposures for sei whales to accumulated acoustic energy above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

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, ROP call for continuous visual observation during activities with mid- and high-frequency acoustic sources; therefore, sei whales that migrate into the operating area would be detected by visual observers. Implementation of ROP 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 RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- and high- frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not likely result in any death or injury to sei whales. At this time, this application does not request authorization for the annual harassment of sei whales by Level B harassment from potential exposure to acoustic sources.

Sperm Whales (*Physeter macrocephalus*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of sperm whales expected to be behaviorally harassed from RDT&E activities after implementation of ROP in the NAVSEA NUWC Keyport Range Complex is 0 (Table 6-26).

Modeling indicates no exposures to accumulated acoustic energy between of 195 dB and 215 dB re 1 μPa^2-s, which is the threshold established indicative of onset TTS. Modeling predicts there will be no exposures for sperm whales to accumulated acoustic energy above 215 dB re 1 μPa^2-s, which is the threshold indicative of onset PTS.

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 making detection more difficult but passive acoustic monitoring can detect and localize sperm whales from their calls (Watwood et al., 2006). Additionally, ROP call for continuous visual observation during activities with mid- or high-frequency acoustic sources; therefore, sperm whales that migrate into the operating area would be detected by visual observers. Implementation of ROP 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- or high-frequency acoustic sources, 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 RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- or high-frequency acoustic sources, the Navy finds that the HRC training events would not result in any death, injury, or harrassment to sperm whales. At this time, this application does not request authorization for the annual harassment of sperm whales by Level B harassment.or Level A harm.

Killer Whale-Southern Resident and all other killer whale stocks Range Complex (*Orcinus orca*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of Southern Resident killer whales predicted to be behaviorally harassed from RDT&E activities after implementation of ROP in the NAVSEA NUWC Keyport Range Complex is 0 (Table 6-26).

Modeling indicates no exposures between 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling predicts there will be no exposures for killer whales to accumulated acoustic energy above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

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, ROP call for continuous visual observation during activities with mid-frequency acoustic sources; therefore, killer whales that migrate into the operating area would be detected by visual observers. Implementation of ROP 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 RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- and high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to killer whales. At this time, this application does not request authorization for the annual harassment of killer whales by Level B harassment or by Level A harassment from potential exposure to acoustic sources.

Steller Sea Lion (*Eumetopia jubatus*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of Steller sea lions predicted to be behaviorally harassed from testing and training in the NAVSEA NUWC Keyport Range Complex is 3 (Table 6-26).

Modeling indicates no exposures to accumulated acoustic energy between of 206 dB and 226 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling indicates that no Steller sea lions would be exposed to accumulated acoustic energy at or above 226 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

Steller sea lions may rest or swim at the surface making them easier to detect than other pinnipeds. It is very likely that lookouts would detect a group of Steller sea lion at the surface. Additionally, ROP call for continuous visual observation during activities with mid- or high-frequency acoustic sources; therefore, Steller sea lions that migrate into the operating area would be detected by visual observers. Implementation of ROP and probability of detecting Steller sea lions reduces the likelihood of exposure.

Based on the model results, behavioral patterns, and the implementation of ROP presented in sections 11.1 for mid- or high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to Steller sea lions. At this time, this application requests authorization for the annual harassment of up to 3 Steller sea lions by Level B harassment.

6.21.6 Estimated Exposures for Non-ESA Species

Minke Whale (*Balaenoptera acutorostrata*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of minke whales predicted to be behaviorally harassed from RDT&E activities after implementation of ROP in the NAVSEA NUWC Keyport Range Complex is 0 (Table 6-26).

Modeling indicates 0 exposures to accumulated acoustic energy between of 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling indicates that no minke whales would be exposed to accumulated acoustic energy at or above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

Minke whales are difficult to spot visually but can be detected using passive acoustic monitoring. Additionally, ROP call for continuous visual observation during activities with mid- and high-frequency acoustic sources; therefore, minke whales that migrate into the operating area would be detected by visual observers or passive acoustic monitoring. Implementation of ROP 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 RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- or high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to minke whales.

Gray Whale (*Eschrichtius robustus*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of gray whales predicted to be behaviorally harassed from RDT&E activities after implementation of ROP in the NAVSEA NUWC Keyport Range Complex is 0 (Table 6-26).

Modeling indicates no exposures to accumulated acoustic energy between 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling for all Alternatives indicates that no gray whales would be exposed to accumulated acoustic energy at or above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

Given the large size (up to 46 ft. [14 m]) of individual gray whales, pronounced vertical 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, ROP call for continuous visual observation during activities with mid- or high-frequency acoustic sources; therefore, gray whales that migrate into the operating area would be detected by visual observers. Implementation of ROP 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 RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- or high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to gray whales. At this time, this application does not request authorization for the harassment of gray whales by Level B harassment.

Dwarf and Pygmy Sperm Whales (*Kogia* sp.)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of dwarf and pygmy sperm whales predicted to be 0 (Table 6-26).

Modeling indicates no exposures to accumulated acoustic energy between 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling for all Alternatives indicates that no dwarf or pygmy sperm whales would be exposed to accumulated acoustic energy at or above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

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, ROP call for continuous visual observation during activities with mid-or high-frequency acoustic sources; therefore, dwarf or pygmy sperm whales that migrate into the operating area would be detected by visual observers. Implementation of ROP and probability of detecting large groups of pygmy sperm whales reduces the likelihood of exposure.

Based on the model results, behavioral patterns, acoustic abilities of dwarf sperm whales, results of past RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- or high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to dwarf sperm whales. At this time, this application does not request authorization for the harassment dwarf or pygmy sperm whale to potential Level B harassment from acoustic sources.

Bairds Beaked Whale (*Beradius bairdii*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of Baird's beaked whales predicted to be behaviorally harassed from RDT&E activities after implementation of ROP in the NAVSEA NUWC Keyport Range Complex is 0 (Table 6-26).

Modeling indicates no exposures to accumulated acoustic energy between 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling for all Alternatives indicates that no Baird's beaked whales would be exposed to accumulated acoustic energy at or above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

ROP call for continuous visual observation during activities with mid- or high-frequency acoustic sources; therefore, Baird's beaked whales that migrate into the operating area would be detected by visual observers. Implementation of ROP and probability of detecting large groups of Baird's beaked whales reduces the likelihood of exposure.

Based on the model results, behavioral patterns, acoustic abilities of Baird's beaked whales, results of past RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- and high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to Baird's beaked whale. At this time, this application does not request authorization for the harassment of Baird's beaked whales to potential Level B harassment from acoustic sources.

Mesoplodonts (Hubb's and Stejneger's beaked whales; *Mesoplodon* sp.)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of mesoplodonts predicted to be behaviorally harassed from RDT&E activities after implementation of ROP in the NAVSEA NUWC Keyport Range Complex is 0 (Table 6-26).

Modeling indicates no exposures to accumulated acoustic energy between 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling for all Alternatives indicates that no Baird's beaked whales would be exposed to accumulated acoustic energy at or above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

ROP call for continuous visual observation during activities with mid- or high-frequency acoustic sources; therefore, mesoplodonts that migrate into the operating area would be detected by visual observers. Implementation of ROP and probability of detecting these whales reduces the likelihood of exposure.

Based on the model results, behavioral patterns, acoustic abilities of mesoplodonts, results of past RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- and high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to mesoplodont whales. At this time, this application does not request authorization for the harassment of mesoplodont whales to potential Level B harassment from acoustic sources.

Risso's Dolphin (*Grampus griseus*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of Risso's dolphins predicted to be behaviorally harassed from RDT&E activities after implementation of ROP in the NAVSEA NUWC Keyport Range Complex is 0 (Table 6-26).

Modeling indicates no exposures to accumulated acoustic energy between 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling for all Alternatives indicates that no Risso's dolphins would be exposed to accumulated acoustic energy at or above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

Given their frequent surfacing, light coloration and large group size of up to several hundred animals (Leatherwood et al. 1982), and 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, ROP call for continuous visual observation during activities with mid- or high-frequency acoustic sources; therefore, Risso's dolphins that migrate into the operating area would be detected by visual observers. Implementation of ROP 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 RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- or high-frequency acoustic sounds, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to Risso's dolphins. At this time, this application does not request authorization for the harassment of Risso's dolphins to potential Level B harassment from acoustic sources.

Pacific White-Sided Dolphin (*Lagenorhynchus obliquidens*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of Pacific white-sided dolphins predicted to be behaviorally harassed from RDT&E activities after implementation of ROP in the NAVSEA NUWC Keyport Range Complex is 0 (Table 6-26).

Modeling indicates no exposures to accumulated acoustic energy between 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling for all Alternatives indicates no exposure to accumulated acoustic energy at or above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

Given their frequent surfacing and large mean group size (probability of trackline detection = 1.00 in Beaufort Sea States of 5 or less; Barlow 2006), it is very likely that lookouts would detect a group of Pacific white-sided dolphins at the surface. Additionally, ROP call for continuous visual observation during activities with mid- or high-frequency acoustic sources; therefore, Pacific white-sided dolphins that migrate into the operating area would be detected by visual observers. Implementation of ROP and probability of detecting 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 RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- or high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to Pacific white-sided dolphins. At this time, this application does not request authorization for the harassment of Pacific white-sided dolphins to potential Level B harassment from acoustic sources.

Short-beaked Common Dolphin (*Delphinus delphinus*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of short-beaked common dolphins predicted to be behaviorally harassed from RDT&E activities after implementation of ROP in the NAVSEA NUWC Keyport Range Complex is 0 (Table 6-26).

Modeling indicates no exposures to accumulated acoustic energy between 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling for all Alternatives indicates no exposure to accumulated acoustic energy at or above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

Given their frequent surfacing and large mean group size (probability of trackline detection = 0.97 in Beaufort Sea States of 6 or less; Forney 2007), it is very likely that lookouts would detect a group of short-beaked common dolphins at the surface. Additionally, ROP call for continuous visual observation during activities with mid- or high-frequency acoustic sources; therefore, short-beaked common dolphins that migrate into the operating area would be detected by visual observers. Implementation of ROP and probability of detecting groups of short-beaked common dolphins reduces the likelihood of exposure.

Based on the model results, behavioral patterns, acoustic abilities of short-beaked common dolphins, results of past RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- or high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to short-beaked common dolphins. At this time, this application does not request authorization for the harassment of short-beaked common dolphins to potential Level B harassment from acoustic sources.

Striped Dolphin (*Stenella coeruleoalba*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of striped dolphins predicted to be behaviorally harassed from RDT&E activities after implementation of ROP in the NAVSEA NUWC Keyport Range Complex is 0 (Table 6-26).

Modeling indicates 0 exposures to accumulated acoustic energy between 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling for all Alternatives indicates no exposure to accumulated acoustic energy at or above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

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, ROP call for continuous visual observation during activities with mid- or high-frequency acoustic sources; therefore, striped dolphins that migrate into the operating area would be detected by visual observers. Implementation of ROP 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 RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- or high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to striped dolphins.

Northern Right Whale Dolphin (*Lissodelphis borealis*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of northern right whale dolphins predicted to be behaviorally harassed from RDT&E activities after implementation of ROP in the NAVSEA NUWC Keyport Range Complex is 0 (Table 6-26).

Modeling indicates no exposures to accumulated acoustic energy between 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling for all Alternatives indicates that no northern right whale dolphins would be exposed to accumulated acoustic energy at or above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

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 northern right whale dolphins at the surface (Leatherwood et al., 1982). Additionally, ROP call for continuous visual observation during activities with mid- or high-frequency acoustic sources; therefore, northern right whale dolphins that migrate into the operating area would be detected by visual observers. Implementation of ROP 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 RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- or high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to northern right whale dolphins. At this time, this application does not request authorization for the annual harassment of northern right whale dolphins by Level B harassment from acoustic sources.

Dall's Porpoise (*Phocoenoides dalli*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of Dall's porpoise predicted to be behaviorally harassed from RDT&E activities after implementation of ROP in the NAVSEA NUWC Keyport Range Complex is 0 (Table 6-26).

Modeling indicates no exposures to accumulated acoustic energy between of 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling for all Alternatives indicates that no Dall's porpoise would be exposed to accumulated acoustic energy at or above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

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 Dall's porpoises at the surface (Leatherwood et al., 1982). Additionally, ROP call for continuous visual observation during activities with mid- or high-frequency acoustic sources; therefore, Dall's porpoises that migrate into the operating area would be detected by visual observers. Implementation of ROP 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 RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- or high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to Dall's porpoise. At this time, this application does not request authorization for the annual harassment of Dall's porpoise by Level B harassment from acoustic sources.

Harbor Porpoise (*Phocoena phocoena*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of harbor porpoise predicted to be behaviorally harassed from testing and training in the NAVSEA NUWC Keyport Range Complex is 11,282 (Table 6-26).

Modeling indicates 1 exposure to accumulated acoustic energy between 195 dB and 215 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling for all Alternatives indicates that no harbor porpoises would be exposed to accumulated acoustic energy at or above 215 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

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, ROP call for continuous visual observation during activities with mid- or high-frequency acoustic 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 porpoise, results of past RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- or high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to harbor porpoise. At this time, this application requests authorization for the annual harassment of up to 11,283 harbor porpoises by Level B harassment from acoustic sources.

Northern Fur Seal (*Callorhinus ursinus*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of northern fur seals predicted to be behaviorally harassed from testing and training in the NAVSEA NUWC Keyport Range Complex is 44 (Table 6-26.

Modeling indicates no exposures to accumulated acoustic energy between 206 dB and 226 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling indicates that no northern fur seals would be exposed to accumulated acoustic energy at or above 226 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

Based on the model results, behavioral patterns, acoustic abilities of northern fur seals, results of past RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- or high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to northern fur seals. At this time, this application requests authorization for the annual harassment of up to 44 northern fur seals by Level B harassment from acoustic sources.

California Sea Lion (*Zalophus californianus*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of California sea lions predicted to be behaviorally harassed from testing and training in the NAVSEA NUWC Keyport Range Complex is 114 (Table 6-26).

Modeling indicates no exposures to accumulated acoustic energy between 206 dB and 226 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling indicates that no California sea lions would be exposed to accumulated acoustic energy at or above 226 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

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. Additionally, ROP call for continuous visual observation during activities with mid- or high-frequency acoustic sources; therefore, California sea lions that migrate into the operating area would be detected by visual observers. Implementation of ROP and probability of detecting large groups of California sea lions reduces the likelihood of exposure.

Based on the model results, behavioral patterns, acoustic abilities of California sea lions, results of past RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- or high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to California sea lions. At this time, this application requests authorization for the annual harassment of up to 114 California sea lions by Level B harassment from acoustic sources.

Northern Elephant Seal (*Mirounga angustirostris*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of northern elephant seals predicted to be behaviorally harassed from testing and training in the NAVSEA NUWC Keyport Range Complex is between 14 (Table 6-26).

Modeling indicates no exposures between 204 dB and 224 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling indicates that 0 northern elephant seals would be exposed to accumulated acoustic energy at or above 224 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

Based on the model results, behavioral patterns, acoustic abilities of northern elephant seals, results of past RDT&E activities, and the implementation of ROP presented in sections 11.1 for mid- or high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to northern elephant seals. At this time, this application requests authorization for the annual harassment of up to 14 northern elephant seals by Level B harassment from acoustic sources.

Pacific Harbor Seal (*Phoca vitulina*)

The modeling results for behavioral effects were calculated using the risk function methodology documented in Section 6.15. Combining all acoustic sources, the annual number of Pacific harbor seals predicted to be behaviorally harassed from testing and training in the NAVSEA NUWC Keyport Range Complex is 3,507 (Table 6-26).

Modeling indicates 2,027 exposures to accumulated acoustic energy between of 183 dB and 203 dB re 1 µPa^2-s, which is the threshold established indicative of onset TTS. Modeling indicates that no Pacific harbor seal would be exposed to accumulated acoustic energy at or above 203 dB re 1 µPa^2-s, which is the threshold indicative of onset PTS.

Based on the model results, behavioral patterns, acoustic abilities of Pacific harbor seals, results of past RDT&E activities, and the implementation of ROP presented in section 11.1 for mid- or high-frequency acoustic sources, the Navy finds that the NAVSEA NUWC Keyport Range Complex RDT&E activities would not result in any death or injury to Pacific harbor seals. At this time, this application requests authorization for the annual harassment of up to 5,534 Pacific harbor seals by Level B harassment from acoustic sources

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7 IMPACTS TO MARINE MAMMAL STOCKS

Overall, the conclusions in this analysis find that impacts to marine mammal species and stocks would be negligible for the following reasons:

- All acoustic harassments are within the non-injurious temporary threshold shift (TTS) or behavioral effects zones (Level B harassment). No exposures to sound levels causing permanent threshold shift (PTS)/injury (Level A harassment) resulted from the summation of the modeling.
- Although the numbers presented in Tables 6-23, 6-24 and 6-25 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). Based on each species’ life history information, the expected behavioral patterns in the NAVSEA NUWC Keyport Range Complex locations, and an analysis of the behavioral disturbance levels in comparison to the overall population, an analysis of the potential impacts of the Proposed Action on species recruitment or survival is presented in Section 6.3 for each species. These species-specific analyses support the conclusion that proposed NAVSEA NUWC Keyport Range Complex RDT&E activities would have a negligible impact on marine mammals.

This authorization request assumes that short-term non-injurious sound exposure levels predicted to cause TTS or temporary behavioral disruptions qualify as Level B harassment. As discussed, this will overestimate reactions qualifying as harassment under MMPA because there is no established scientific correlation between mid- or high-frequency acoustic source use and long term abandonment or significant alteration of behavioral patterns in marine mammals. As detailed in Table 6-26, the total Level B takes is 17,023 and the total Level A takes is 0 in this authorization request.

The Navy does not anticipate that marine mammal strandings or mortality will result from the operation of mid- or high-frequency acoustic sources during Navy RDT&E activities within the NAVSEA NUWC Keyport Range Complex.

8 IMPACTS ON SUBSISTENCE USE

The NAVSEA NUWC Keyport Range Complex and proposed extensions will not affect the availability of a species or stock of marine mammal for subsistence uses.

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9 IMPACTS TO THE MARINE MAMMAL HABITAT AND THE LIKELIHOOD OF RESTORATION

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. Other sources that may affect marine mammal habitat were considered and potentially include the introduction of fuel, debris, ordnance, and chemical residues into the water column. The effects of each of these components will be considered in the NAVSEA NUWC Keyport Range Complex Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS). Marine mammal habitat would not be affected.

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10 IMPACTS TO MARINE MAMMALS FROM LOSS OR MODIFICATION OF 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

11.1 Operating Policies and Procedures

As stated previously, mitigating potential impacts to the environment during RDT&E activities in the NAVSEA NUWC Keyport Range Complex Extension are accomplished through strict adherence to operating policies and procedures. Operating policies and procedures, as described in NUWC Keyport Report 1509, *Range Operating Policies and Procedures Manual (ROP)*, are followed for all NUWC Keyport range activities. NUWC Keyport will continue to implement the ROP policies and procedures within the NAVSEA NUWC Keyport Range Complex with implementation of any of the proposed range-site alternatives, including the No-Action Alternative. The ROP is followed to protect the health and safety of the public and Navy personnel and equipment as well as to protect the marine environment. The policies and procedures address issues such as safety, development of approved run plans, range operation personnel responsibility, deficiency reporting, all facets of range activities, and the establishment of ‘exclusion zones’ to ensure that there are no marine mammals within a prescribed area prior to the commencement of each in-water exercise within the NAVSEA NUWC Keyport Range Complex. All range operators are trained by NOAA in marine mammal identification, and active acoustic activities are suspended or delayed if whales, dolphins, or porpoises (cetaceans) are observed within range areas. Table 11-1 provides a summary of selected ROP sections and other range procedures. The ROP contains additional sections; only the sections that specifically apply to this analysis are covered here.

The ROP sections shown in Table 11-1 apply to current NAVSEA NUWC Keyport Range Complex activities at the Keyport Range Site, DBRC Site, and QUTR Site, and they would also apply to proposed activities within the current and proposed range site boundaries. The policies and procedures outlined in the ROP are continually being updated as new environmental and health and safety information becomes available. In addition, the ROP may be revised in the future to reflect any conservation or mitigation measures that arise from ongoing agency consultations (e.g., NMFS) regarding this EIS/OEIS.

Because the analysis concludes that there are minimal or no impacts to marine mammals, no further mitigation measures are necessary.

Table 11-1 NAVSEA NUWC Keyport Range Complex ROP Sections and General Flight Rules

ROP	*ROP Description*
ROP 10-1 (Revision E, June 2004)	• Establishes policies and procedures to be followed in the event of an OTTO Fuel II spill within the NAVSEA NUWC Keyport Range Complex or aboard a NUWC Keyport craft during the loading/off-loading, retrieval/recovery, or stowage of test units containing OTTO Fuel II;and the handling of OTTO Fuel II waste material or reclaimable liquids by range or craft personnel.
ROP 10-4 *Safety/Environmental Requirements and Operational Restrictions for Test Units* (Revision E, June 2004)	• Establishes safety/environmental requirements and operational restrictions for all test units (this includes but is not limited to, torpedoes, mobile targets, inert mines, UUVs, and research and developmental vehicles) to be tested within the NAVSEA NUWC Keyport Range Complex or used in support of range activities.
ROP 6-4 *Range Operations and Marine Mammals* (Revision E, June 2004)	• Ensures that NAVSEA NUWC Keyport Range Complex personnel from NUWC Keyport are in compliance with OPNAVINST 5090.1C, *Navy Environmental and Natural Resources Program Manual*; MMPA; and Endangered Species Act (ESA). In particular, the following marine mammal protection measures are implemented per ROP 6-4: 1. Range activities shall be conducted in such a way as to ensure marine mammals are not harassed or harmed by human-caused events. 2. Marine mammal observers are on board ship during range activities. All range personnel shall be trained in marine mammal recognition. Marine mammal observer training is normally conducted by qualified organizations such as NOAA/National Marine Mammal Lab (NMML) on an as needed basis.

ROP	*ROP Description*
	3. Vessels on a range use safety lookouts during all hours of range activities. Lookout duties include looking for any and all objects in the water, including marine mammals. These lookouts are not necessarily looking only for marine mammals. They have other duties while aboard. All sightings are reported to the Range Officer in charge of overseeing the activity. 4. Visual surveillance shall be accomplished just prior to all in-water exercises. This surveillance shall ensure that no marine mammals are visible within the boundaries of the area within which the test unit is expected to be operating. Surveillance shall include, as a minimum, monitoring from all participating surface craft and, where available, adjacent shore sites. 5. The Navy shall postpone activities until cetaceans (whales, dolphins, and porpoises) leave the project area. When cetaceans have been sighted in an area, all range participants increase vigilance and take reasonable and practicable actions to avoid collisions and activities that may 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). 6. In accordance with the MMPA and ESA, which address marine mammal protection, an "exclusion zone" shall be established and surveillance will be conducted to ensure that there are no marine mammals within this exclusion zone prior to the commencement of each in-water exercise. For cetaceans (whales, dolphins, and porpoises), the exclusion zone must be at least as large as the entire area within which the test unit may operate, and must extend at least 1,000 yards (914.4 m) from the intended track of the test unit. For pinnipeds, the exclusion zone extends out 100 yards (91 m) from the intended track of the test unit. 7. The minimum marine mammal exclusion zones defined above are sufficient to mitigate the effects of the acoustic energy transmitted by the test units, range tracking equipment, and the range target simulators currently in operation on U.S. ranges as of this writing. The exclusion zones specified in ROP 6-4 meet the requirements of Navy (2002a, 2003b) and NOAA (1993) and thereby ensure that active acoustic emissions from the acoustic sources currently in use do not constitute marine mammal harassment. 8. The NMFS recommendation that vessels not approach within 100 yards (91 m) of marine mammals shall be followed to the extent practicable considering human and vessel safety priorities. All Navy vessels and aircraft, including helicopters, are expected to comply with this directive. This includes marine mammals "hauled-out" on islands, rocks, and other areas such as buoys. 9. In the event of a collision between a Navy vessel and a marine mammal, NUWC Keyport activities will notify the Navy chain of Command, which would result in notification to NMFS. 10. Passive acoustic monitoring shall be utilized to detect marine mammals in the area before and during activities, especially when visibility is reduced. 11. Procedures for reporting marine mammal sightings on the NAVSEA NUWC Keyport Range Complex shall be promulgated, and sightings shall be entered into the Range Operating System and forwarded to NOAA/NMML Platforms of Opportunity Program.
Flight Rules for Wildlife (per Navy 2001a, 2002a)	General flight rules for terrestrial and marine wildlife include: • Flights over land must be at least 1,000 ft (305 m) above the level of the land; • Flights over water must be at least 500 ft (152 m) above the level of the sea; and • Flights within 500 yards (457 m) of the shore (beach) must be at least 1,000 ft (305 m) above sea level. • A 656-ft (200-m) lateral no-fly area around bald eagle nests for all aircraft (Navy 2001a, 2002a).

11.2 Conservation Measures

The Navy will continue to fund ongoing marine mammal research. Results of conservation efforts by the Navy in other locations will also be used to support efforts in the Pacific Northwest. The Navy is coordinating both short and long term monitoring/studies of marine mammals on various established ranges and operating areas to determine the response of marine mammals to Navy sound sources and the effectiveness of mitigation measures:

- Coordinating with NMFS to conduct surveys within the Pacific Northwest Operating Areas as part of a baseline monitoring program.
- Implementing a long-term monitoring program of marine mammal populations in the Pacific Northwest Operating Areas, including evaluation of trends.
- Implementing a monitoring program of marine mammals in the NAVSEA NUWC Keyport Range Complex Extension during RDT&E activities.
- Continuing Navy research and Navy contribution to university/external research to improve the state of the science regarding marine species biology and acoustic effects.
- Sharing data with NMFS and via the literature for research and development efforts.

The Navy has contracted with a consortium of researchers from the University of Hawaii, LGL, Ltd., Greeneridge Scientific, University of St. Andrews, and SRS Technologies to conduct a pilot study analysis and develop a survey and monitoring plan that lays out the recommended approach for surveys (aerial/shipboard, frequency, spatial extent, etc.) and data analysis (standard line-transect, spatial modeling, etc.) necessary to establish a baseline of protected species distribution and abundance and monitor for changes that might be attributed to RDT&E operations within the NAVSEA NUWC Keyport Range Complex Extension. The Research Design for the project will be utilized in implementing similar programs in the Southern California RDT&E operations areas.

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12 MINIMIZATION OF ADVERSE EFFECTS ON SUBSTINENCE USE

The NAVSEA NUWC Keyport Range Complex and proposed extensions will not affect the availability of a species or stock of marine mammal for Arctic subsistence uses.

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13 MONITORING AND REPORTING MEASURES

The monitoring and reporting requirements in the ROP are incorporated into the training required for certification as a range officer and craft master. Range officers have control of all operations on the range. Each craft operating in the NAVSEA NUWC Keyport Range Complex is requiredx to have a certified craft master on board. A Run Plan and range users in brief, will be conducted prior to each RDT&E activity 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 this Chapter and Chapter 14.

13.1 Marine Species Monitoring Plans

The Navy is developing two separate marine species monitoring plans: a general short-term monitoring plan that can be used for different exercises in a various locations; and long-term monitoring plans specific to a Navy range complex/geographic area. Depending on the type of exercise and the area it is conducted in, the operators can choose the appropriate monitoring elements from this plan.

13.1.1 Short-Term Exercise Monitoring Plan

The Navy is developing a monitoring program for training activity. While this monitoring program does not cover RDT&E activities in the NAVSEA NUWC Keyport Range Complex, it could readily be adapted for RDT&E if deemed necessary. The study design of this monitoring program provides the power to estimate:

- The number of ESA listed species that are exposed to mid-frequency acoustic sources within 1,000 yds (initial safety zone for 6 dB power down) during training activities.
- The behavioral or other observable responses of any of these marine mammals that are exposed to mid- and high-frequency acoustic sources at these received levels.
- The effectiveness of the Navy’s entire suite of mitigation measures at avoiding exposing any of these marine mammals to mid- and high-frequency acoustic sources.
- The effectiveness of the different measures contained in the Navy’s suite of mitigation measures at avoiding exposing any of these marine mammals to mid- and high-frequency acoustic sources.

This monitoring plan is being developed to address the concerns of the National Marine Fisheries Service (NMFS) and to supplement a long-term monitoring plan which is also under development. It is understood that the monitoring plans will likely require further revision in an iterative process as the methodology is refined based on the data that is returned.

13.1.2 Long-Term Exercise Monitoring Plan

The Navy is developing long-term monitoring plans to determine behavioral and population level changes to marine mammals within Navy ranges. These plans will continue or initiate studies of abundance, distribution, habitat utilization, etc for sensitive species of concern using visual surveys, passive and acoustic monitoring, radar and data logging tags (satellite or radio linked to record data on acoustics, diving and foraging behavior, and movements). They will determine the geographic and temporal extent of key habitats and comprehensive baseline information to account for natural perturbations such as El Niño events as well as use observational data and baseline information to determine the spatial and temporal extent of reactions to Navy operations, or indirect effects from changes in prey availability and distribution.

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14 RESEARCH

The Navy will continue to fund ongoing marine mammal research, and results of these efforts by the Navy in other locations will also be used to support marine mammal conservation efforts in the area of the NAVSEA NUWC Keyport Range Complex. The Navy is planning to coordinate long-term monitoring/studies of marine mammals on various established ranges and operating areas:

- Coordinating with National Marine Fisheries Service (NMFS) to conduct surveys within the selected Range Complex as part of a baseline monitoring program. A long-term monitoring program of marine mammal populations within the Range Complex, including evaluation of trends
- Continuing Navy research and Navy contribution to university/external research to improve the state of the science regarding marine species biology and acoustic effects.
- Sharing data with NMFS and via the literature for research and development efforts. The Navy has contracted with a consortium of researchers from Duke University, University of North Carolina at Wilmington, University of St. Andrews, and the NMFS Northeast Fisheries Science Center to conduct a pilot study analysis and develop a survey and monitoring plan that lays out the recommended approach for surveys (aerial/shipboard, frequency, spatial extent, etc.) and data analysis (standard line-transect, spatial modeling, etc.) necessary to establish a baseline of protected species distribution and abundance and monitor for changes that might be attributed to anti-submarine warfare (ASW) operations on the East Coast Underwater Training Range. The Research Design for the project will be utilized in implementing similar programs in the Range Complex ASW operations areas. A similar research and monitoring project has been initiated in the Hawaiian Islands and the remainder of the Pacific Fleet Operating Areas.

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APPENDIX A: MARINE MAMMAL DENSITIES AND DEPTH DISTRIBUTION

A.1 INTRODUCTION

Marine mammal species occurring in the offshore and inland waters of Washington State include baleen whales (mysticetes), toothed whales (odontocetes) and seals and sea lions (commonly referred to as pinnipeds); sea otters are found near the QUTR Site only. 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 more 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, a conservative approach has been adopted with reference 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.

The QUTR Site, located west of Washington State and overlapping somewhat with Olympic Coast National Marine Sanctuary (OCNMS), is the largest in geographic size and has the greatest diversity of marine mammal species (see Table A-1). There are three proposed surf zone extension alternatives, Kalaloch, Ocean City and Pacific Beach (Figure A-1). For most marine mammal species, the surf zone alternative has no impact on density because species distribution is expected to overlap the entire area. For a few cetaceans (gray whale, harbor porpoises) and pinnipeds (California sea lion and harbor seal), the surf zone could potentially influence density or percentage of habitat within QUTR, so independent calculations were completed for each zone.

The DBRC Site, located in Hood Canal, has approximately six marine mammal species (two mysticetes, three odontocetes and one pinniped) with some regularity although most of these species do not occur often enough for abundance or density to be known. Note that lack of estimates for some species does not indicate that they are not present; rather it indicates that they have not been sufficiently or systematically studied to yield data suitable for generating abundance or density estimates. There are two proposed extensions to DBRC: a southward extension only and both a north and south extension (Figure A-1).

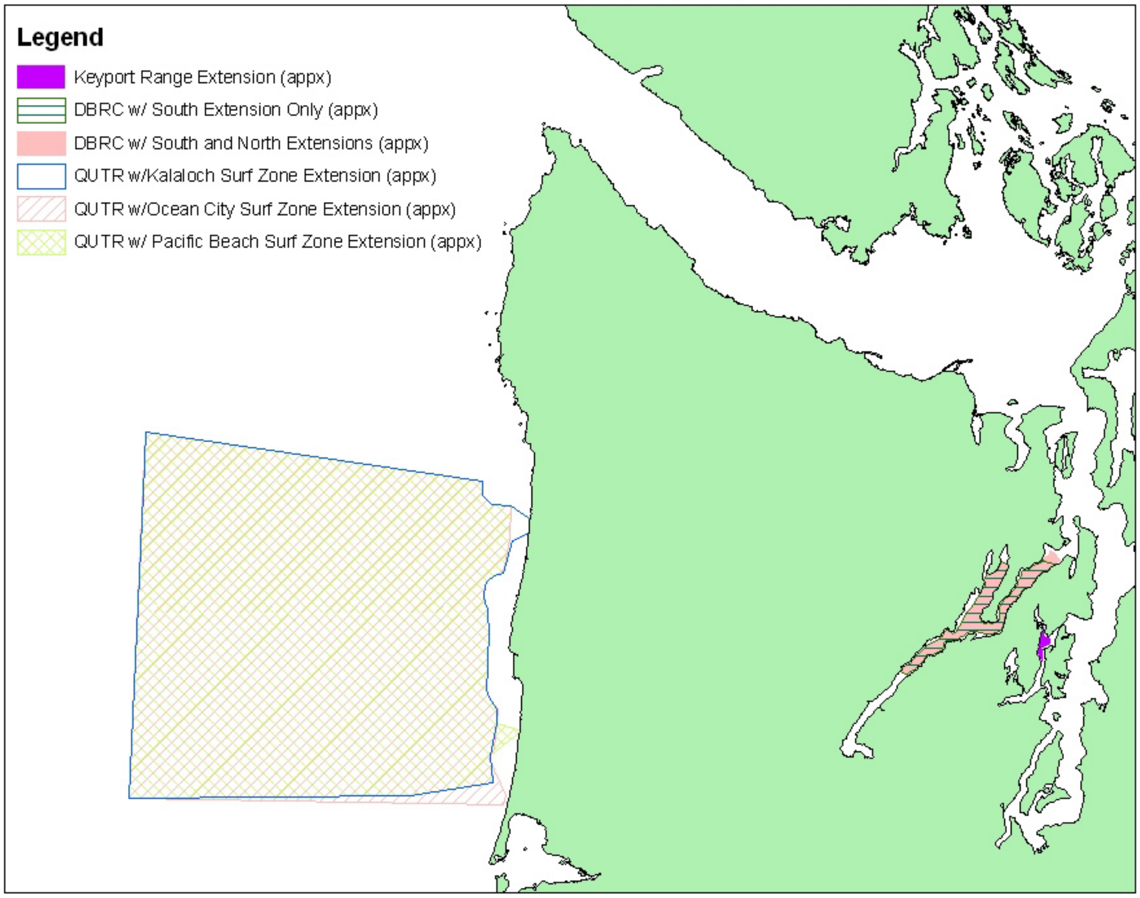

Figure A-1. The NAVSEA NUWC Keyport Range Complex and Proposed Extensions

The Keyport Range Site, located between the Kitsap Peninsula and Bainbridge Island, is the smallest of the three ranges. Only two species of cetaceans (gray and killer whales) have been sighted in the vicinity of the Keyport range site, and their occurrence is rare and transitory. The transient nature of cetaceans within the Keyport Range Site means that abundance or density values are not available. It should be noted that the absence of cetacean density values for the Keyport Range Site does not indicate that they are completely absent. It is possible that killer whales and gray whales, as well as minke whales, Dall's porpoise and harbor porpoise, could occasionally be found within the range. Harbor seals are regularly seen in the Keyport area (Table A-1). Due to the extremely small size of the range (~5.2 km^2), simple mitigation procedures, such as visual observations to detect dorsal fins or water vapor from blow exhalations, prior to the start of activities would eliminate any potential impacts to cetaceans on the Keyport Range Site. Harbor seals are regularly seen in the Keyport area (Table A-1). There is one proposed expansion to Keyport (Figure A-1).

Table A-1. Summary of Marine Mammal Densities for QUTR, DBRC, and Keyport Range Sites

Common Name	*Scientific Name*	*Status*	*Range*	*Density/km^2*	*Season*	*Source*	*Notes*
MYSTICETES							
Blue whale	*Balaenoptera musculus*	Endangered	QUTR	0.0003	May-Oct	Barlow (2003: 2001 estimate)	
Fin whale	*B. physalus*	Endangered	QUTR	0.0012	Year round	Barlow (2003); Forney (2007)	
Sei whale	*B. borealis*	Endangered	QUTR	0.0002	Year round	Forney (2007)	
Minke whale	*B. acutorostrata*		QUTR	0.0004	Year round	Barlow (2003)	
			DBRC	0	Year round		
Humpback whale	*Megaptera novaeangliae*	Endangered	QUTR	0.0237	Jun-Oct	Forney (2007)	
				0	Nov-May		
Gray whale	*Eschrichtius robustus*		QUTR	0.003	Year round	Calambokidis et al. (2004)	Applies to 41% of QUTR
			DBRC	0	Year round		
			Keyport	0	Year round		
ODONTOCETES							
Sperm whale	*Physeter catodon*	Endangered	QUTR	0.0011	Year round	Forney (2007)	
Dwarf and pygmy sperm whales	*Kogia* sp.		QUTR	0.0015	May-Oct	Barlow (2003: 1996 estimate)	
Baird's beaked whale	*Berardius bairdii*		QUTR	0.0027	Year round	Forney (2007)	
Mesoplodonts, including Hubb's and Stejneger's beaked whales	*Mesoplodon* sp.		QUTR	0.0027	Year round	Forney (2007)	
Killer whale	*Orcinus orca*	Endangered	QUTR	0.0028	Year round	Forney (2007)	
			DBRC	0.038	Jan-Jun	London (2006)	
			DBRC	0	Jul - Dec		
			Keyport	0	Year round		
Risso's dolphin	*Grampus griseus*		QUTR	0.002	Year round	Forney (2007)	
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*		QUTR	0.1929	May-Oct	Forney (2007)	
Short-beaked common dolphin	*Delphinus delphinus*		QUTR	0.0012	May-Oct	Barlow (2003: 2001 estimate)	
Striped dolphin	*Stenella coeruleoalba*		QUTR	0.0002	May-Oct	Barlow (2003: 1996 estimate)	
Northern right whale dolphin	*Lissodelphis borealis*		QUTR	0.0419	Year round	Forney (2007)	
Dall's porpoise	*Phocoenoides dalli*		QUTR	0.1718	Year round	Forney (2007)	
			DBRC	0	Year round		
Harbor porpoise	*Phocoena phocoena*		QUTR	2.86	Year round	Laake (2007)	Applies to 24% of QUTR

Common Name	*Scientific Name*	*Status*	*Range*	*Density/km^2*	*Season*	*Source*	*Notes*
			DBRC	0	Year round		
CARNIVORES - Pinnipeds (seals and sea lions)							
Northern fur seal	*Callorhinus ursinus*		QUTR	0.117	Nov-May	National Marine Fisheries Service (NMFS) (2006a); Carretta et al. (2007)	
				0.091	Jun-Oct		
Steller sea lion	*Eumetopias jubatus*	Threatened	QUTR	0.0096	Year round	Angliss and Outlaw (2007); Bonnell and Bowlby (1992)	
California sea lion	*Zalophus californianus*		QUTR	0.283	Aug-Apr	Jeffries et al. (2000)	Applies to 6% of QUTR
				0	May-Jul		
			DBRC	0.052	Aug-Apr	Jeffries et al. (2000)	
				0	May-Jul		
Northern elephant seal	*Mirounga angustirostris*		QUTR	0.019	Dec-Feb	Caretta et al. (2007); Lowry (2002)	
				0.026	Mar-Apr		
				0.038	May-Jul		
				0.047	Aug-Nov		
Harbor seal	*Phoca vitulina*		QUTR	0.44	Year round	Jeffries et al. (2003); Huber et al. (2001)	Applies to 52% of QUTR
			DBRC	1.31	Year round		
			Keyport	0.55	Year round	Jeffries et al. (2003)	
CARNIVORES - Sea otters							
Sea otter	*Enhydra lutris*		QUTR	0	Year round	Lance et al. (2004)	only within 2 km of shore; distribution does not overlap with QUTR

A.2 DENSITY

Survey data for the inland waters of Puget Sound are sparse. There have been few comprehensive studies of marine mammals in inland waters, and those that have occurred have focused on inland waters farther north (e.g., Strait of Juan de Fuca, San Juan/Gulf Islands, Strait of Georgia) (Osmek et al. 1998). Most published information focuses on single species (e.g., harbor seals, Jeffries et al. 2003) or are stock assessment reports published annually by the National Marine Fisheries Service (NMFS) (e.g., Carretta et al. 2007).

Survey data for the offshore waters of Washington State, including the area of the QUTR Site, are somewhat better, particularly for cetaceans. The NMFS conducted vessel surveys in the region in 1996 and 2001, which are summarized in Barlow (2003) and Appler et al. (2004). Vessel surveys were again conducted by NMFS in summer 2005, and included finer-scale survey lines within the OCNMS (Forney 2007). Cetacean densities from this most recent effort were used wherever possible (Table A-1); older density values (2001 or 1996) were used when more recent values were not available. Species with rare or extralimital occurrence off Washington State are included in the species summaries; however, there are no densities available and they are not included in Table A-1. Some cetacean densities (gray and killer whale, harbor porpoise) were obtained from sources other than the broad scale surveys indicated above and the methodologies of deriving the densities are included here in some detail.

Pinniped at-sea density is not often available because pinniped abundance is most often obtained via shore counts of animals at known rookeries and haulouts. Therefore, densities of pinnipeds were derived differently from those of cetaceans. Several parameters were identified from the literature, including area of stock occurrence, number of animals (which may vary seasonally) and season, and those parameters were then used to calculate density. Determining density in this manner is risky as the parameters used usually contain error (e.g., geographic range is not exactly known and needs to be estimated, abundance estimates usually have large variances) and, as is true of all density estimates, it assumes that animals are always distributed evenly within an area which is likely never true. However, this remains one of the few means available to determine at-sea density for pinnipeds.

Sea otters occur along the northern Washington coast. Density of sea otters was published as animals/km, which was modified to provide density per area.

Some cetacean and pinniped geographic distributions do not overlap the entire area of each proposed QUTR surf zone alternative and, in those cases, density was further refined as the percentage of the QUTR that is actually overlapped by the species distribution. Species distributions were taken from published literature accounts.

Brief species summaries are included for all marine mammals whose distribution extends to the Pacific Northwest coast, even if rarely seen. Additional information on all species is available in the Pacific Northwest Operating Area Marine Resource Assessment (Department of the Navy, 2006), a recent publication that includes most of the pertinent literature published to date. That publication listed seven mysticetes, 19 odontocetes, six pinnipeds, and one fissiped as occurring or possibly occurring in the NAVSEA NUWC ranges (Department of the Navy 2006; Tables 3-1 and 3-3). However, several of the species listed are rare or extralimital and do not regularly occur. Only species with regular occurrence and for which densities are available are included in Table A-1.

A.3 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 and some beaked 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.

Summary depth distribution information for marine mammal species occurring regularly in the NAVSEA NUWC Keyport Range Complex, and for which densities are available, is provided in Table A-2. More detailed depth information for species for which densities are available is included in Table A-3. located at the end of this Appendix.

A.4 DENSITY AND 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 correct. 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.

Table A-2. Summary of Marine Mammal Depth Distributions for NAVSEA NUWC Ranges.

Common Name	**Scientific Name**	**Depth Distribution**	**Reference**
MYSTICETES - Baleen whales			
Blue whale	*Balaenoptera musculus*	78% at 0-16m, 9% at 17-32 m, 13% at >32 m	Lagerquist et al. (2000)
Fin whale	*B. physalus*	40% at <50m, 20% at 50-225m, 40% at >225m	Goldbogen et al. (2006)
Sei whale	*B. borealis*	53% at <20m, 47% at 21-65m	extrapolated from minke whale (Blix and Folkow, 1995)
Minke whale	*B. acutorostrata*	53% at <20m, 47% at 21-65m	Blic and Folkow (1995)
Humpback whale	*Megaptera novaeangliae*	37% at <4m, 25% at 4-20m, 7% at 21-35m,4% at 36-50m, 6% at 51-100m, 7% at 101-150m, 8% at 151-200m, 6% at 201-300m, <1% at >300m	Dietz et al. (2002)
Gray whale	*Eschrichtius robustus*	40% at <3 m, 38% at 3-18 m, 22% at >18 m	Malcolm et al. (1995/96); Malcolm and Duffus (2000)
ODONTOCETES - Toothed whales			
Sperm whale	*Physeter catodon*	31% at <10 m, 8% at 10-200 m, 9% at 201-400 m, 9% at 401-600 m, 9% at 601-800 m and 34% at >800 m	Amano and Yoshioka (2003)
Dwarf and pygmy sperm whales	*Kogia sp.*	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 >835 m	extrapolated from Blainville's beaked whale (Tyack et al., 2006)
Baird's beaked whale	*Berardius bairdii*	34% at 0-40 m, 39% at 41-800 m, 27% at >800 m	extrapolated from northern bottlenose whale (Hooker and Baird, 1999)
Mesoplodonts	*Mesoplodon sp.*	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 >835 m	extrapolated from Blainville's beaked whale (Tyack et al., 2006)
Killer whale	*Orcinus orca*	96% at 0-30 m, 4% at >30 m	Baird et al. (2003)
Risso's dolphin	*Grampus griseus*	50% at <50 m, 15% at 51-200 m, 15% at 201-400 m, 10% at 401-600 m and 10% at >600 m	Blanco et al. (2006); Baumgartner (1997)
Striped dolphin	*Stenella coeruleoalba*	Daytime: 89% at 0-10 m, 11% at 11-50 m, and <1% at 51-122 m; Nighttime: 80% at 0-10 m, 8% at 11-20 m, 2% at 21-30 m, 2% at 31-40 m, 2% at 41-50 m, and 6% at 51-213 m	extrapolated from pantropical spotted dolphin (Baird et al. 2001)
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*	Daytime: 100% at 0-65 m; Nighttime: 100% at 0-130 m	extrapolated from other *Lagenorhynchus* (Mate et al., 1994; Benoit-Bird et al., 2004)
Short-beaked common dolphin	*Delphinus delphinus*	100% at 0-200m	Ohizumi et al. (1998); Pusineri et al. (2007); Chou et al. (1995); Perrin (2002b)
Northern right whale dolphin	*Lissodelphis borealis*	Daytime: 100% at 0-50 m; Nighttime: 100% at 0-400 m	extrapolated from spinner dolphin (Benoit-Bird and Au, 2003)
Dall's porpoise	*Phocoenoides dalli*	39% at <1 m, 8% at 1-10 m, 45% at 11-40 m, and 8% at >40 m	Hanson and Baird (1998)
Harbor porpoise	*Phocoena phocoena*	75% at 0-20 m, 15% at 21-40 m, and 10% at >40 m	Otani et al. (1998)
CARNIVORES - Pinnipeds			
Northern fur seal	*Callorhinus ursinus*	Daytime: 100% at 0-210 m; Nighttime: 100% at 0-75 m	Ponganis et al. (1992); Kooyman and Goebel (1986); Sterling and Ream (2004); Gentry et al. (1986)
Steller sea lion	*Eumetopias jubatus*	60% at 0-10 m, 22% at 11-20 m, 12% at 21-50 m, 5% at 51-100 m and 1% at >100 m	Merrick and Loughlin (1997)
California sea lion	*Zalophus californianus*	26% at <2 m, 41% at 2-10 m, 3% at 11-19 m, 17% at 20-60 m and 13% at >60 m	Feldkamp et al. (1989)
Northern elephant seal	*Mirounga angustirostris*	9% at <2 m, 11% at 2-100 m, 11% at 101-200 m, 11% at 201-300 m, 11% at 301-400 m, 11% at 401-500 m and 36% at >500 m	Asaga et al. (1994)
Harbor seal	*Phoca vitulina*	50% at <3 m, 20% at 3-50 m, 25% at 51-100 m and 5% at >100 m	Eguchi and Harvey (2005)

This document is organized into taxonomic categories: Mysticetes, Odontocetes, and Carnivores, which includes pinnipeds and sea otters. Species for which distribution summaries were included are those listed in the Marine Resource Assessment (MRA) for the Pacific Northwest Operating Area (Department of the Navy 2006; Table 3-1). However, many of the species included in the MRA are rare or extralimital in Washington waters and do not regularly occur on the Keyport Range Site, DBRC Site, or QUTR Site. Only species with regular occurrence and for which density is available are included in Table A-1. Nomenclature was adopted from the Integrated Taxonomic Information System (www.itis.gov). Distribution and density summaries are followed by discussions of depth distribution for those species that have regular occurrence.

A.5 MYSTICETES

Blue Whale – QUTR Site

Up to five stocks of blue whale may currently exist in the north Pacific, including an Eastern North Pacific population, which winters as far south as the eastern tropical Pacific and feeds near California in summer/fall. This is the only stock for which abundance is available (2005 population estimate = 1,774; Carretta et al. 2007). Blue whales have been seen during vessel surveys as far north as Oregon, although none were seen off Washington during surveys conducted in 1996, 2001 and 2005 (Appler et al. 2004; Barlow 2003; Forney 2007). Density of blue whales was estimated at 0.0003/km2, based on surveys conducted in 2001 off Oregon and Washington (Barlow 2003); this estimate is applicable to the QUTR Site from May-October. Density is zero for the DBRC and Keyport Range sites; blue whales are not known to occur in inland Washington waters.

Blue whales feed on euphausiid crustaceans, including Euphausia sp and Thysanoessa sp (Sears 2002). They have been documented feeding near the surface as well as at depths exceeding 140 m (Croll et al. 2001). Data from southern California and Mexico showed that whales dived to >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 were deeper than traveling dives; traveling dives were generally to ~ 30m. Typical dive shape was somewhat V-shaped, although the bottom of the V was wide to account for the vertical lunges at bottom of the dive. Blue whales also have shallower foraging dives. The best information available for % of time at depth is from Lagerquist et al (2000; Figure 2): 78% in 0-16 m, 9% in 17-32 m, 13% in >32 m; most dives were to <16 m and 96-152 m ranges, but only 1.2% of total time was spent in the deeper range.

Fin Whale – QUTR Site

Fin whales occur in all oceans in temperate to polar latitudes, and many populations undergo seasonal migrations, from low latitude breeding areas to higher latitude feeding areas (Aguilar 2002). This seasonal cycle is less defined in the northern hemisphere. The most current population estimate for the California/Oregon/Washington stock of fin whales is 3,279, based on vessel surveys conducted in the summer of 1996 and 2001. Fin whales were sighted offshore Washington and Oregon in 1996, 2001, and 2005 (Appler et al. 2004; Barlow 2003; Forney 2007). Fin whales were detected acoustically on SOSUS hydrophone arrays nearly year round from September 1991-August 1992 (Moore et al. 1998). Densities of fin whales from surveys conducted offshore Washington and Oregon in 2001 and 2005 were both 0.0012/ km^2 (Table A-1), which is applicable to the Quinault region year round. Fin whales are not known to occur in the inland waters of Washington State; the density of fin whales on the DBRC and Keyport Range sites is zero.

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 (<100m) and night dives were deeper (>400m). 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 (<50m); dives were to >225 m and were characterized by rapid gliding ascent, foraging lunges near the bottom of the dive, and rapid ascent with flukes. Dives were somewhat V-shaped although the bottom of the V was wide. Based on this information, percentage of time at depth levels is estimated as 40% at <50m, 20% at 50-225 m (covering the ascent and descent times) and 40% at >225 m.

<u>Sei whale – QUTR Site</u>

Sei whales occur in all oceans from subtropical to sub-arctic waters, and can be found on the shelf as well as in oceanic waters (Reeves et al. 2002). They are known to occur in the Gulf of Alaska and as far north as the Bering Sea in the north Pacific. However, their distribution is poorly understood. The only stock estimate for US waters is for the eastern north Pacific stock offshore of California, Oregon and Washington (Carretta et al. 2007). Sei whales were not seen during vessel surveys conducted off Washington in 1996, 2001, or 2005 (Appler et al. 2004; Barlow 2003; Forney 2007); there were two sightings of sei whales offshore south-central Oregon in 2005 (Forney 2007). Density of sei whales for the Oregon/Washington stratum in 2005 was 0.0002/km2 (Table A-1), which is applicable to the QUTR Site year round. Sei whales are not known to occur in inland Washington waters; there are no density estimates available for QUTR, DBRC, or Keyport Range sites.

Sei whales feed on copepods, amphipods, euphausiids, schooling fish and squid (Horwood 2002). They appear to be skim feeders that feed on swarms of prey at fairly low densities (Nemoto and Kawamura 1977). There are no depth distribution data and very little information on preferred habitat. In lieu of other information, the depth distribution for minke whales will be extrapolated to sei whales: 53% at <20 m and 47% at 21-65 m.

<u>Minke Whale – QUTR Site</u>

Minke whales are the smallest of all mysticete whales. They are widely distributed in the north Atlantic and Pacific. Minkes can be found in nearshore shallow waters and have been detected acoustically in offshore deep waters. Most minke whale populations inhabit colder waters in summer and migrate to warmer regions in winter. However, in the inland waters of Puget Sound, particularly around the San Juan Islands and in Johnstone Strait between Vancouver Island and mainland British Columbia, they appear to show some site fidelity and may not undergo extensive migrations (Dorsey et al. 1990). The most current population estimate for the California/Oregon/Washington stock of minke whales is 1,015, based on vessel surveys conducted in the summer of 1996 and 2001. Minke whales were sighted offshore Washington and Oregon in both 1996 and 2001 (Appler et al. 2004; Barlow 2003), but were not sighted during CSCAPE 2005 surveys conducted in June (Forney 2007). Density of minke whales from surveys conducted offshore Washington and Oregon in 2001 was 0.0004/km^2 (Table A-1), which is applicable to the QUTR Range Site year round. Density for minke whales on the DBRC Site and Keyport Range Site is zero; minke whales have been sighted in Hood Canal (Angell and Balcomb 1982) and a few strandings have been recorded (Norman et al. 2004), but they are infrequent visitors.

Minke whales feed on small schooling fish and krill, and are the smallest of all balaenopterid species, which may affect their ability to dive. The only depth distribution data for this species were 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) was representative of a 75-minute 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 21-65 m.

Humpback Whale – QUTR Site

Humpback whales are found in all oceans, in both coastal and continental waters as well as near seamounts and in deep water during migration (Reeves et al. 2002). Some populations have been extensively studied (e.g., Hawaii, Alaska, Caribbean), and details about migratory timing, feeding and breeding areas are fairly well known. Humpbacks are highly migratory, feeding in summer at mid and high latitudes and calving and breeding in winter in tropical or subtropical waters. Humpbacks of the Eastern North Pacific stock appear to spend winter and spring near Central America and Mexico and migrate north to California, Oregon, Washington and British Columbia in summer and fall (Carretta et al. 2007). The most recent stock estimate, based on photo identification mark-recapture surveys conducted from 1991-2003, is 1,391 whales (Calambokidis et al. 2004a). Humpback whales were sighted offshore Washington and Oregon in both 1996 and 2001 (Appler et al. 2004; Barlow 2003), and there were several sightings during CSCAPE 2005 surveys conducted in 2005 (Forney 2007). Density of humpbacks from surveys conducted in the OCNMS stratum in 2005 (Forney 2007) was 0.0237/km2 (Table A-1), which is applicable for the QUTR Site for June-October. Humpback whales were once plentiful enough in the inland waters of Washington State that whaling stations were present at Victoria, British Columbia, and in the Strait of Georgia. However, their occurrence in inland waters is now rare; density for humpback whales on the DBRC and Keyport Range sites is zero.

Humpback whales feed on pelagic schooling euphausiids and small fish including capelin, herring and mackerel (Clapham 2002). 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 minutes) with the deepest dive to 148 m (southeast Alaska; Dolphin 1987), while whales observed feeding on Stellwagen Bank in the north Atlantic dove to <40 m (Hain et al. 1995). Depth distribution data collected at a feeding area in Greenland resulted in the following estimation of depth distribution: 37% of time at <4 m, 25% of time at 4-20 m, 7% of time at 21-35m, 4% of time at 36-50 m, 6% of time at 51-100 m, 7% of time at 101-150 m, 8% of time at 151-200 m, 6% of time at 201-300 m, and <1% at >300 m (Dietz et al. 2002).

Gray whale – QUTR Site

Gray whales inhabit shallow coastal waters of the northeastern Pacific, from Baja California north to Arctic Alaska (a separate small remnant stock of gray whales also ranges in the northwestern Pacific). The current estimate for the Eastern North Pacific stock of gray whales is 18,813 (Angliss and Outlaw 2007), which is based on a census conducted during the southbound migration in 2001-02. Gray whales from the Eastern North Pacific stock undertake a well-documented migration from winter calving lagoons in Baja California to summer feeding areas in the Bering and Chukchi seas (Swartz et al. 2006). The migration route is primarily near shore in shallow water, although gray whales have been documented swimming offshore near the Channel Islands in the Southern California Bight. Green et al. (1995) noted that the migration corridor along Oregon and Washington expanded to approximately 43 km in some locations. In addition to the Bering and Chukchi sea feeding areas, gray whales are known to feed opportunistically at several locations along the migratory route (e.g., Oregon; Newell and Cowles 2006), and several whales remain on these opportunistic feeding grounds throughout the year. Calambokidis et al. (2004b) estimated annual abundance of "resident" gray whales in the Pacific Northwest from 1998-2003 using photo identification methods. The Pacific Coast Feeding Aggregation, covering an area stretching from northern California to southeast Alaska, was estimated at 261-298 whales. The estimate for Oregon to British Columbia (excluding Alaska and California) was 197-256 whales. Gray whales would, therefore, likely be present in the nearshore regions of the QUTR Site on a year round basis. To determine density, the maximum number of gray whales estimated for Oregon to British Columbia (256) was divided by the area offshore Oregon, Washington and British Columbia out to 43 km offshore (estimated at 79,650 km^2 via ArcMap; see Figure A-2 for depiction of this area) for a value of 0.003/km^2 (256 gray whales/79,650 km^2; Table A-1). This density is applicable only to the nearshore waters of Washington State, which represents 41% of the QUTR Site (see Figure A-2 for depiction of this area).

Gray whales are seen annually in northern Puget Sound, particularly the waters around Whidbey Island. They are occasionally seen in Hood Canal, and there were several recorded gray whale strandings in that area (Norman et al. 2004). A gray whale stranded at the Kitsap Navy Base in Bremerton in May 2005 (Cascadia Research 2005). These occasional sightings and strandings indicate that while gray whales occur in the inland waters of Washington State, they do not occur in high enough numbers to permit density to be calculated; density for gray whales on the DBRC and Keyport Range sites is zero.

Gray whales migrate from breeding and calving grounds in Baja California to primary feeding grounds in the Bering and Chukchi seas. Behavior, including diving depth and frequency, can vary greatly between geographic regions. Gray whales feed on the bottom, mainly on benthic amphipods that are filtered from the sediment (Reeves et al. 2002), so foraging dive depth is dependent on depth at the foraging location. There have been several studies of gray whale movement within the Baja lagoons (Harvey and Mate 1984; Mate and Harvey 1984), but these are likely not applicable to gray whales elsewhere. 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. 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: 40% of time at <3 m (surface and interventilation dives), 38% of time at 3-18 m (active migration), 22% of time at >18 m (foraging).

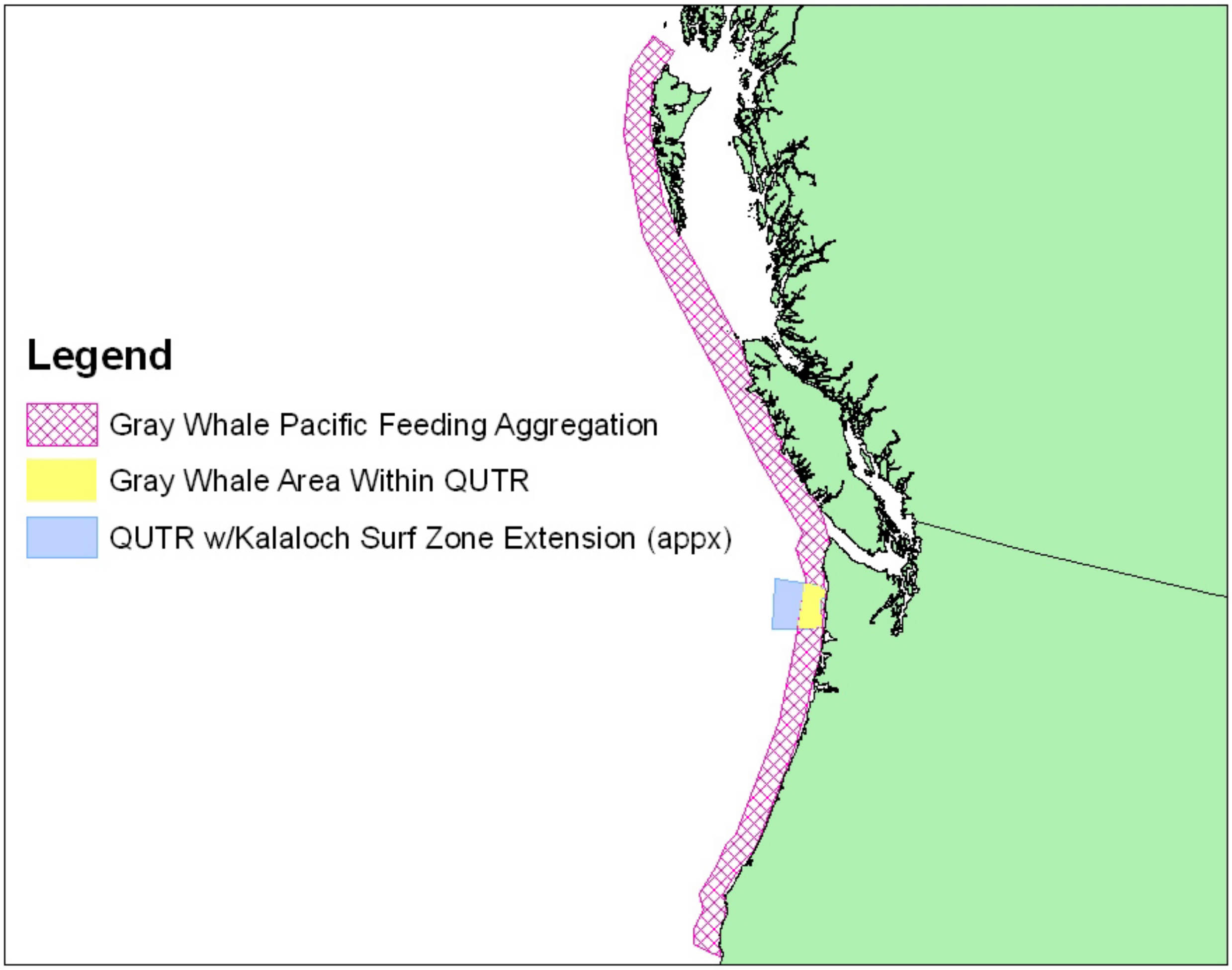

Figure A-2. Area of Pacific Coast Feeding Aggregation of Gray Whales off Oregon, Washington, and British Columbia and area of QUTR Site for Which Density is Applicable. Only the Kalaloch Surf Zone extension is shown.

North Pacific Right Whale – QUTR Site

North Pacific right whales range across the northern Pacific, from the Bering Sea south to Japan in the west and California in the east. They occur mostly in coastal and shelf waters but have been sighted well offshore (Reeves et al. 2002). Although right whales were heavily hunted throughout their range from the mid-1800s through the early 1900s, they were rarely caught in coastal fisheries along the North American west coast (Clapham et al. 2004). Despite international protection, the species has not recovered and remains one of the rarest of all cetaceans. They likely undertake northward migrations in the spring returning to more southern latitudes in fall, but the only regular recent sightings of right whales in the north Pacific have been since 1996 on the eastern Bering Sea shelf (e.g., Goddard and Rugh 1998). One right whale was positively identified offshore of Washington in May 1992 (Rowlett et al. 1994). Right whales may be present in winter in extremely low numbers in the QUTR Site but are not known to inhabit inland Washington waters; there are no density estimates available for QUTR, DBRC, or Keyport Range sites.

A.6 ODONTOCETES

Sperm Whale – QUTR Site

Sperm whales are most often found in deep water, near submarine canyons, and along the edges of banks and over continental slopes (Reeves et al. 2002). Adult males range farther north than females and juvenile males which tend to inhabit waters >1000 m deep and north to 50°N in the north Pacific. Vessel surveys conducted in 1996 and 2001 offshore Oregon and Washington yielded several sightings, and abundance for the California/Oregon/Washington stock was estimated at 1,233 (Angliss and Outlaw 2007). Density for sperm whales from the Olympic Coast –Slope stratum (Forney 2007) was estimated at 0.0011/km2 (Table A-1), and is applicable on the QUTR Site year round. Sperm whales are not known to inhabit inland Washington waters; density for sperm whales on the DBRC and Keyport Range sites is zero.

Unlike other cetaceans, there is a large body of dive information for this species, most likely because it is the deepest diver of all cetacean species and therefore generates a lot of interest. Sperm whales feed on large and medium-sized squid, octopus, rays and sharks, on or near the ocean floor. Some evidence suggests that they do not always dive to the bottom of the sea floor (likely if food is elsewhere in the water column), but that they generally feed at the bottom of the dive. Davis et al. (2007) report that dive-depths (100-500 m) of sperm whales in the Gulf of California overlapped with depth distributions (200-400 m) of jumbo squid, based on data from satellite-linked dive recorders placed on both species, particularly during daytime hours. Their research also showed that sperm whales foraged throughout a 24-hour period, and that they rarely dove to the sea-floor bottom (>1000 m). The most consistent sperm whale dive type is U-shaped, during which the whale makes a rapid descent to the bottom of the dive, forages at various velocities while at depth (likely while chasing prey) and then ascends rapidly to the surface. Perhaps the best source for depth distribution data comes from Amano and Yoshioka (2003), who attached a tag to a female sperm whale near Japan in an area where water depth was 1000-1500m. Based on values in Amano and Yoskioka 2003 for dives with active bottom periods, the total dive sequence was 45.9 minutes (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 (<10 m) of 31%. Mean bottom time divided by total time (17.5/45.9) and adjusted to include the percentage of time at the surface between dives, yields a percentage of time at the bottom of the dive (in this case >800 m as the mean maximum depth was 840 m) of 34%. Total time in the water column descending or ascending results from the duration of dive minus bottom time (37.4-17.5) or ~20 minutes. Assuming a fairly equal descent and ascent rate (as shown in Table 1 in Amano and Yoshioka 2003) 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, 0-200 m = 2.5 minutes one direction (which correlates well with the descent/ascent rates provided) and therefore 5 minutes for both directions. Same for 201-400 m, 401-600 m and 601-800 m. Therefore, the depth distribution for sperm whales based on information in the Amano paper is: 31% in <10 m, 8% in 10-200 m, 9% in 201-400 m, 9% in 401-600 m, 9% in 601-800 m and 34% in >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.

Dwarf and Pygmy Sperm Whales – QUTR Site

Dwarf (*Kogia simus*) and pygmy (*Kogia breviceps*) sperm whales are difficult to differentiate at-sea, and are therefore often recorded as *Kogia* sp. during survey efforts. The distribution of both species is generally temperate to tropical and probably seaward of the continental shelf (Reeves et al. 2002). There is a single record of a dwarf sperm whale stranding from British Columbia (Willis and Baird 1998) and four pygmy sperm whales are known to have stranded in Washington (Norman et al. 2004). The most recent stock estimate for the California/Oregon/Washington stock of *Kogia* sp. was 247 (Carretta et al. 2007). There was one sighting of *Kogia* offshore Oregon/Washington in 1996, no sightings in 2001 (Barlow 2003) and no sightings in 2005 (Forney 2007). Density of *Kogia* was estimated as 0.0015 based on surveys conducted in 1996 (Barlow 2003); this estimate is applicable to the QUTR Site from May-October. There are no density estimates available for the Dabob Bay or Keyport ranges.

There are no depth distribution data for *Kogia*. An attempt to record dive information on a rehabbed pygmy sperm whale failed when the time depth recorder (TDR) package was never recovered (Scott et al. 2001). Prey preference appears to be cephalopods, crustaceans and fish, and there is some evidence that they feed at the bottom. Beatson (2007) found that stomach contents of pygmy sperm whales stranded in New Zealand consisted primarily of immature cephalopods (*Histioteuthis*), which are known to undergo vertical migrations, as well as mysids that are usually found at 650 m during day and between 274 and 650 m at night. A pygmy sperm whale that stranded in Atlantic Canada contained squid beaks, a fish otolith and crustaceans, and the squid species were representative of mesopelagic slope-water community (McAlpine et al. 1997). 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 beaked whale undertakes shallower non-foraging dives in-between deep foraging dives. Blainville's beaked whale depth distribution data, taken from Tyack et al. (2006) 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 >835 m.

Cuvier's Beaked Whale – QUTR Site

Cuvier's beaked whale has the widest distribution of all beaked whales, and occurs in all oceans. It is most often found in deep offshore waters, and appears to prefer slope waters with steep depth gradients. As with most beaked whales, Cuvier's are fairly cryptic at-sea and therefore difficult to sight and identify. The best abundance estimate for Cuvier's beaked whales for the California/Oregon/Washington stock, based on vessel surveys conducted in 1996 and 2001, is 1,884 (Barlow 2003). No density is provided in Barlow (2003) for either *Ziphius cavirostris* or Ziphiid whales. This species was also not seen during surveys conducted in 2005 in the OCNMS (Forney 2007). Numerous strandings have been recorded along the outer coast (Figure 10 in Norman et al. 2004). Cuvier's beaked whales may be present in very low numbers in the QUTR Site and are not known to inhabit inland Washington waters; there are no density estimates available for QUTR, DBRC, or Keyport Range Sites.

Baird's Beaked Whale – QUTR Site

Baird's beaked whales, like most beaked whales, are a deep water species that inhabits the north Pacific. They generally occur close to shore only in areas with a narrow continental shelf. The most current population estimate for the California/Oregon/Washington stock of Baird's beaked whales is 228, based on vessel surveys conducted in summer 1996 and 2001 (Angliss and Outlaw 2007). Density for the Oregon and Washington stratum, calculated from vessel surveys in 2005 (Forney 2007), is 0.0027/km^2 (Table A-1), which is applicable to the QUTR Site year round. Baird's beaked whales have not been sighted nor have strandings been recorded in Puget Sound; density for the DBRC and Keyport Range sites is zero.

There are no depth distribution data for this species. Studies conducted on the diet of Baird's beaked whales from stomach content analysis reveal some insight into feeding patterns. Samples collected off the Pacific coast of Honshu, Japan, revealed a preference primarily for benthopelagic fish (87%) and cephalopods (13%), while samples collected in the southern Sea of Okhotsk were primarily cephalopods (Walker et al. 2002). Other stomach samples collected from same geographic regions indicated demersal fish were the most commonly identified prey, and that Baird's beaked whales were feeding at the bottommost depths of at least 1,000 m (Ohizumi et al. 2003). The overall dive behavior of this beaked whale is not known (e.g., shape of dive, interventilation dives, etc). In lieu of other information, the depth distribution for northern bottlenose whales, *Hyperoodon ampullatus,* will be extrapolated to Baird's. beaked whales. 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*.

Hubb's Beaked Whale and Stejneger's Beaked Whale – QUTR Site

Hubb's beaked whales are known only from temperate waters of the north Pacific, mainly along the west coast of North America (Reeves et al. 2002). Stejneger's beaked whale ranges across arctic and cool temperate waters from Baja California to Japan. Both *Mesoplodon* species have stranded along the Washington coastline (Norman et al. 2004). Very little is known about the behavior of either species, as they are cryptic and difficult to sight at-sea; only one of the Mesoplodonts sighted during vessel surveys off California, Oregon and Washington in 1996, 2001 and 2005 was identified to species (Angliss and Outlaw 2007; Forney 2007), and that sighting was identified as *Mesoplodon densirostris*. One unidentified Mesoplodont was sighted in the Oregon/Washington stratum during vessel surveys in 2005 (Forney 2007). The habits of these species, combined with recent (1996) recorded sightings offshore Washington, indicate that they may be likely to occur in the QUTR Site. Density for the Oregon/Washington stratum (Forney 2007) for Mesoplodont beaked whales was calculated as 0.0027/km2 (Table A-1), which is applicable for Mesoplodon sp. in the QUTR Site year round. Beaked whales have not been sighted nor have strandings been recorded in Puget Sound; density for the DBRC and Keyport Range sites is zero.

Mesoplodonts feed primarily on mesopelagic squid and some fish. They are likely suction feeders, based on the relative lack of teeth and enlarged hyoid bone and tongue muscles (Pitman 2002). There are no depth distribution data for *Mesoplodon* species as a group. In lieu of any other information, Blainville's beaked whale depth distribution data, taken from Tyack et al. (2006), will be extrapolated to *Mesoplodon* species beaked whales: 26% in <2 m (surface); 41% in 2-71 m; 2% in 72-200 m; 4% in 201-400 m; 4% in 401-600 m; 4% in 601-835; 19% in >835 m.

Killer Whale – QUTR and DBRC Sites

There are four stocks of killer whales in the north Pacific that can be found at least seasonally in inland and offshore waters of Washington State, but who differ in feeding preferences, acoustics and genetics; each of these stocks appears to be reproductively isolated from the others. The Eastern North Pacific Southern Resident stock feeds primarily on fish, and ranges from the inland waters of Washington and southern British Columbia to nearshore waters as far north as the Queen Charlotte Islands of British Columbia and south to at least central California (Wiles 2004). The latest published NMFS count of the three pods in the Southern Resident Stock is 91 (Carretta et al. 2007). Southern resident pods are present in the inland waters of Washington primarily in summer (May-November), with occurrence centered in Georgia Basin and Haro Strait. In fall, occurrence may shift to Puget Sound as residents take advantage of returning chum and Chinook salmon (Wiles 2004). The Eastern North Pacific Northern Resident stock also feeds on fish, but its range is primarily the inland waters of British Columbia. This stock, which numbers approximately 16 pods, will occasionally venture into the Strait of Juan de Fuca and offshore of the Olympic Peninsula of Washington (Wiles 2004). The Eastern North Pacific Offshore Stock is found year round ranging from offshore California north to offshore Washington and occasionally British Columbia, and also apparently feeds primarily on fish. The current stock estimate is 466 animals; 211 have been photo-identified (Carretta et al. 2007). The West Coast Transient stock ranges year round from Alaska to California, and feeds primarily on other marine mammals. The minimum estimate based on photo ID for that population is 314.

Density for killer whales in the OCNMS stratum (Forney 2007) was estimated at 0.0028/km^2 (Table A-1), which is applicable year round for the QUTR Site; this density does not differentiate between killer whale stocks (i.e., likely includes killer whales from more than one stock).

Density for killer whales in inland waters is more difficult to determine, due to the seasonality and inconsistency of occurrence by both transient and resident pods in those regions. There are no published densities for killer whales in inland waters. Resident killer whales have not been observed in Dabob Bay, but transient pods were observed in Hood Canal for lengthy periods of time in 2003 (January-March) and 2005 (February-June), feeding on harbor seals (London 2006). To determine density, the maximum number of transient killer whales (11) observed at any one time was divided by the area of Hood Canal (estimated at 291 km2 via ArcMap; see Figure A-3 for depiction of this area) for a value of 0.038/km2 (11 killer whales/291 km2; Table A-1), and is applicable for the DBRC Site for January-June. Killer whales have occasionally been seen in the Keyport area, but incidence is low and transitory; density is zero for the Keyport Range Site.

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 264 m, and males dove more frequently and more often to depths >100 m than females, with fewer deep dives at night. Dives to deeper depths were often characterized by velocity bursts that may be associated with foraging or social activities. Using best available data from Baird et al. (2003), it would appear that killer whales spend ~4% of time at depths >30 m and 96% of time at depths 0-30 m.

False killer whale – QUTR Site

False killer whales are found in tropical to warm temperate waters, with well known populations near Japan and in the eastern tropical Pacific. They were not seen along the Pacific US coast during surveys conducted from 1986-2001 (Ferguson and Barlow 2003; Barlow 2003) nor in 2005 (Forney 2007). They have occasionally been sighted as far north as British Columbia (Reeves et al. 2002) and two were reported stranded along the Washington coast from 1930-2002, both in El Nino years (Norman et al. 2004). False killer whales may occur in extremely low numbers in the QUTR Site but are not known at all from Puget Sound; there are no density estimates available for the QUTR, DBRC, or Keyport Range sites.

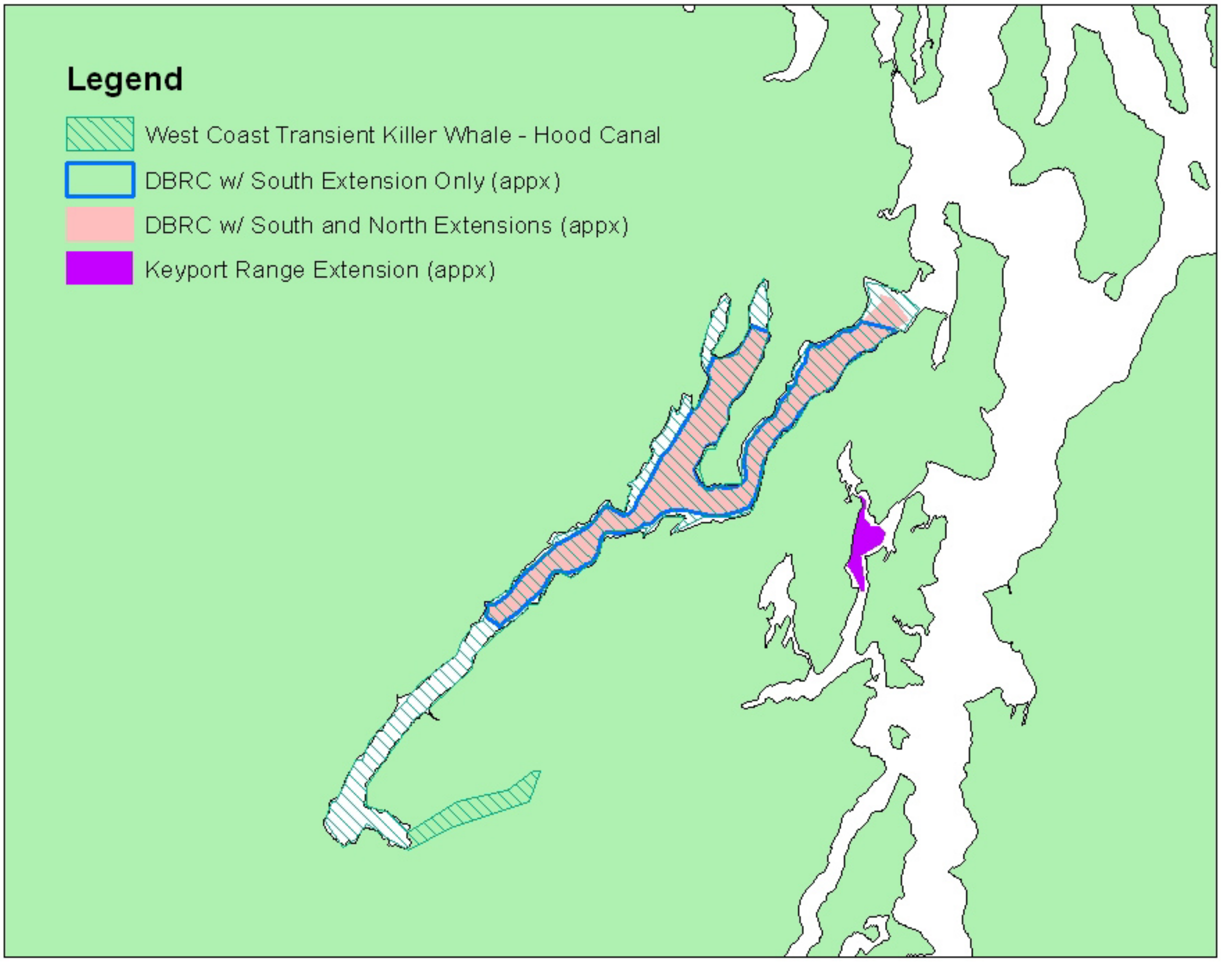

Figure A-3. Area of West Coast Transient Killer Whales Used to Calculate Density for DBRC Site

<u>Short-finned Pilot Whale – QUTR Site</u>

This species is known from tropical and warm temperate waters and, in the northeast Pacific, its distribution may extend as far north as Vancouver Island (Reeves et al. 2002). Pilot whales were not seen during vessel surveys conducted offshore Washington and Oregon in 1996 or 2001 (Barlow 2003) or 2005 (Forney 2007). All six pilot whale strandings recorded in Washington state from 1930-2002 occurred during El Nino years when warmer ocean currents are carried farther north than usual. Short-finned pilot whales may occur in low numbers in the QUTR Site but is not known from Puget Sound; there are no density estimates available for the QUTR, DBRC, or Keyport Range sites.

<u>Risso's Dolphin – QUTR Site</u>

This species is known from tropical and warm temperate oceans, primarily in waters with surface temperatures between 50 and 82˚F (Reeves et al. 2002). They are usually found in water depths exceeding 300 m but are also found on the continental shelf. There were several *Grampus* sighted offshore Washington during vessel surveys conducted in 2001 (Appler et al. 2004), although none were sighted during surveys in 2005 (Forney 2007); the closest sighting was off north-central Oregon. Density for Risso's dolphins in the Oregon/Washington stratum (Forney 2007) was estimated at 0.002/km^2 (Table

A-1), which is applicable year round for the QUTR Site. Risso's dolphins are not known from inland Washington waters; density for the DBRC and Keyport Range sites is zero.

There are no depth distribution data for this species. 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 350 m and 975 m isobaths. That data agreed 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 dolphins feed on the middle slope at depths ranging from 600-800 m. In lieu of any true depth distribution information or information on the shape of dives, the following are very rough estimates of time at depth: 50% at <50 m, 15% at 51-200 m, 15% at 201-400 m, 10% at 401-600 m and 10% at >600 m.

Bottlenose Dolphin – QUTR Site

Bottlenose dolphins are distributed in all oceans from temperate to tropical latitudes. In the eastern north Pacific, the distribution extends to about central California, although distribution of Atlantic bottlenose dolphins extends much farther north (to 60˚N; Reeves et al. 2002). There has been only one occurrence of a bottlenose dolphin in Washington State (Ferrero and Tsunoda 1989). Bottlenose dolphins are likely extremely rare and extralimital in Washington waters; there are no density estimates available for the QUTR, DBRC, or Keyport Range sites.

Rough-toothed Dolphin – QUTR Site

Rough-toothed dolphins are distributed in warm temperate to tropical waters of all oceans. In the eastern north Pacific, the distribution extends north to Baja California (Reeves et al. 2002). There are two records of stranded rough-toothed dolphins in Washington State, both of which occurred during El Nino years when warmer water occurred farther north (Norman et al. 2004). Rough-toothed dolphins are likely extremely rare and extralimital in Washington waters; there are no density estimates available for the QUTR, DBRC, or Keyport Range sites.

Striped Dolphin – QUTR Site

Striped dolphins are distributed in tropical and warm temperate waters of all oceans. In the Eastern North Pacific, their distribution extends as far north as Washington, although there have been few sightings (Appler et al. 2004). Strandings of this species from 1930-2002 occurred far more frequently in Oregon (10) than in Washington (2) (Norman et al. 2004), which also might be indicative of a more southerly distribution. There was a single sighting of striped dolphins in the Oregon/Washington stratum in 1996, and no sightings in either 2001 or 2005 (Barlow 2003; Forney 2007). Density was estimated as 0.0002/km2 based on surveys conducted in 1996 (Barlow 2003); this estimate is applicable to the QUTR Site from May-October. There are no density estimates available for the Dabob Bay or Keyport ranges.

Striped dolphins feed on pelagic fish and squid and may dive during feeding to depths exceeding 200 m (Archer 2002). However, studies are rare on this species. Stomach content remains from three dolphins in the Mediterranean included several species of cephalopod as well as some fish, and suggested that striped dolphins may not feed quite as deep as Risso's dolphins (Ozturk et al. 2007). There is some evidence that striped dolphins feed at night to take advantage of vertical migrations of the deep scattering layer. In lieu of other information, pantropical spotted dolphin depth distribution data will be extrapolated to striped dolphins. One study on pantropical spotted dolphins in Hawaii contains dive information (Baird et al. 2001). The biggest differences recorded were in the increase in dive activity at night. During the day, 89% of time was spent within 0-10 m, most of the rest of the time was 10-50 m, and the deepest dive was to

122 m. At night, only 59% of time was spent from 0-10 m and the deepest dive was to 213 m; dives were especially pronounced at dusk. For activities conducted during daytime-only, the depth distribution would be 89% at 0-10 m and 11% at 11-50 m, with <1% at 51-122 m. For activities conducted over a 24-hour period, the depth distribution needs to be modified to reflect less time at surface and deeper depth dives; 80% at 0-10 m, 8% at 11-20 m, 2% at 21-30 m, 2% at 31-40 m, 2% at 41-50 m, and 6% at 51-213 m.

Pacific White-sided Dolphin – QUTR Site

Pacific white-sided dolphins range throughout the north Pacific in cold temperate waters. Movements between inshore/offshore and north/south are not well understood, but most sightings are in shelf and slope waters and distribution appears to shift northward off Oregon and Washington in late spring and summer (Carretta et al. 2007). The California/Oregon/Washington stock of this species is currently estimated at 59,274, based on data collected during vessel surveys conducted in 1996 and 2001 (Barlow 2003). There were several sightings of this species during vessel surveys conducted in 2005 (Forney 2007); density calculated for the OCNMS stratum from 2005 surveys was 0.1929/km2 (Table A-1), which is applicable to the QUTR Site from May-October. This species is not known to occur in Puget Sound; density for the DBRC and Keyport Range sites is zero.

Pacific white-sided dolphins are generalist feeders (von Waerebeek and Wursig 2002). Studies on diving by this species have not been undertaken. Satellite tag studies of a rehabilitated related species (Lagenorhynchus acutus) in the Gulf of Maine indicated that nearly all time was spent in waters <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 130 m depth to take advantage of the deep scattering layer closer to the surface and during the day in shallower depths (<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 0-65 m; night time – 100% at 0-130 m.

Short-beaked Common Dolphin – QUTR Site

Short-beaked common dolphins are found in continental shelf waters of the Atlantic and Pacific, as well as pelagic waters of the eastern tropical Pacific and Hawaii (Reeves et al. 2002). Distribution in the eastern north Pacific extends as far north as the California/Oregon border, based on sightings in 2001; there have been few sightings or strandings farther north (Appler et al. 2004; Forney 2007; Norman et al. 2004). There were single sightings in 2001 and 2005 of common dolphins in the Oregon/Washington stratum, but both sightings occurred off southern Oregon. Density was estimated as 0.0012 based on surveys conducted in 2001 (Barlow 2003), which is applicable to the QUTR Site for May-October. This species is not known to occur in Puget Sound; density is zero for the DBRC and Keyport Range sites.

Common dolphins feed on small schooling fish as well as squid and crustaceans, and prey preference varies with 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 200 m, but there have been no detailed studies of diving behavior. Based on this limited information, depth distribution is estimated as 100% at 0-200m.

Northern Right Whale Dolphin – QUTR Site

The northern right whale dolphin occurs in a band across the north Pacific, generally between 34˚ and 47˚N (Reeves et al. 2002). They are primarily an open ocean species, and rarely come near shore.

Northern right whale dolphin abundance, based on surveys conducted in 1996 and 2001, is estimated at 20,362 (Carretta et al. 2007). Density calculated from surveys in the Olympic Coast-Slope stratum in 2005 (Forney 2007) was 0.0419/km^2 (Table A-1), which is applicable to the QUTR Site year round. This species is not known to occur in Puget Sound; density for the DBRC and Keyport Range sites is zero.

There are no depth distribution data for this species. They feed on small fish, especially lanternfish and squid (Lipsky 2002), and are believed to take advantage of the deep scattering layer around 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 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 (0-400 m) waters. Prey distribution during the day is estimated at 400-700 m. Based on these data, the following are very rough order estimates of time at depth: daytime: 100% at 0-50 m; nighttime: 100% at 0-400 m.

Dall's Porpoise – QUTR Site

Dall's porpoises are endemic to the north Pacific, ranging north of ~32˚N into the Bering Sea. They are generally found in deep, cool waters but are also common in coastal areas. The California/Oregon/Washington stock is currently estimated at 98,617 animals (Carretta et al. 2007). Density of Dall's porpoise in the Olympic Coast-Slope stratum in 2005 (Forney 2007) was estimated at 0.1718/km^2 (Table A-1), which is applicable to the QUTR Site year round. Dall's porpoise have stranded both along the Washington coast as well as in inland waters, and they are occasionally observed in Puget Sound. Their use of inland Washington waters, however, is mostly limited to the Strait of Juan de Fuca; the expected density for the DBRC and Keyport Range sites is zero.

Dall's porpoise feed on a wide variety of schooling fish, including herring and anchovies, mesopelagic fish including deep-sea smelts, and squids (Jefferson 2002). One study of this species includes dive information for a single animal (Hanson and Baird 1998). The authors concluded that the animal responded to the TDR tag for the initial eight minutes it was in place. Therefore, using data only from dives 7-17 (after the abnormally deep high velocity dive) in Table 2 of Hanson and Baird (1998), total time of the sequence was 26.5 minutes (from start of dive 7 to end of dive 17). 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.

Harbor Porpoise – QUTR Site

Harbor porpoise are found in coastal regions of northern temperate and subarctic waters (Reeves et al. 2002). They are found year round in nearshore waters off the Washington coast (known as the Oregon-Washington Coast Stock) as well as in inland waters (known as the Washington Inland Waters Stock). Harbor porpoise are generally not found in water deeper than 100 m, and decline linearly as depth increases (Carretta et al. 2001; Barlow 1988; Angliss and Outlaw 2007). Abundance for each stock was determined based on aerial surveys conducted in 2002 and 2003. The Coastal Stock, from Cape Blanco, Oregon, north to Cape Flattery, Washington, was estimated at 37,735 animals (Carretta et al. 2007). Abundance and density for subregions of the Coastal Stock were provided by Jeff Laake based on aerial surveys conducted in 2002 (Laake 2007). Density for region "F", which most closely approximates the Quinault area, was calculated by Laake (2007) as 2.86/km^2 (Table A-1). This density is applicable only to that portion of region "F" within the QUTR Site, which represents 24% (1,704 km^2/ 7,036 km^2) of the QUTR Site (see Figure A-4 for depiction of this area).

The 2002 surveys did not extend south into Puget Sound or Hood Canal. Harbor porpoise are occasionally seen in Hood Canal and elsewhere in southern Puget Sound, however, their occurrence there is rare; density for DBRC and Keyport Range sites is zero.

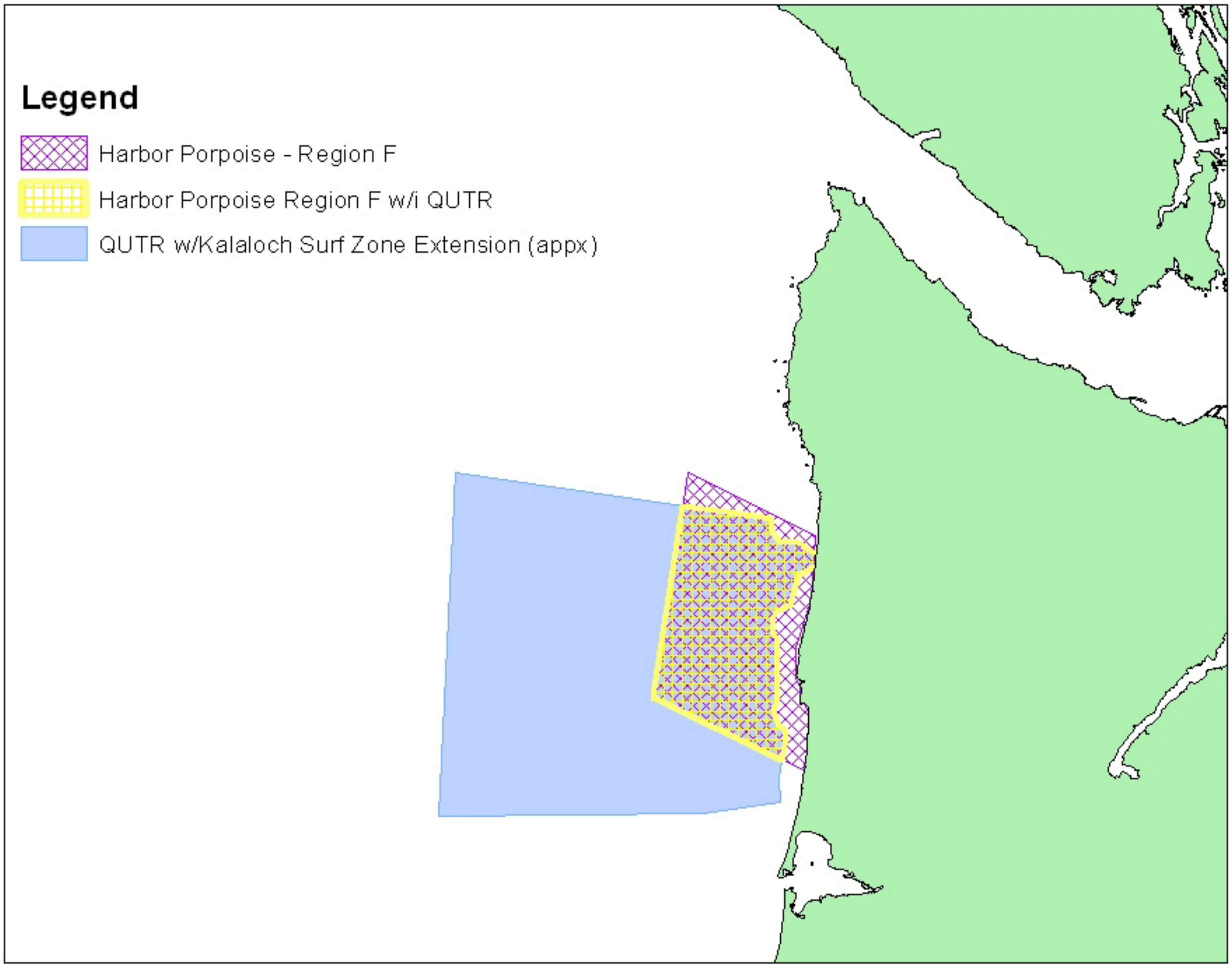

Figure A-4. Depiction of Region "F" from Laake (2007) for which Density was Adopted, and Area of Region "F" Within QUTR Site for which that Density is Applicable.

Harbor porpoise eat fish and squid, and may feed on or near the sea floor at depths <200m (Bjorge and Tolley 2002). Harbor porpoise depth distribution has been studied in the north Atlantic (Bay of Fundy; Westgate et al. 1995) and northwest Pacific (Hokkaido, Japan; Otani et al. 1998, 2000). In the northwest Pacific, two porpoises were initially caught in set nets and, after a short rehabilitation period, were released in Funka Bay, Hokkaido, Japan (Otani et al. 1998). More than 70% of their diving times were at ≤20 m, with most shallow dives V-shaped and very little bottom time (Otani et al. 1998). Deeper dives

(>90 m) were U-shaped; daytime dives did not differ significantly from nighttime dives. Dive durations were short (mean maximums of 1.1 and 1.6 minutes), and number of dives per hour averaged 28-35 (Otani et al. 1998). A study of seven porpoises conducted in the Bay of Fundy, Maine, had similar results as in Japan (>50% of dive time at ≤20 m), but also demonstrated that porpoises are capable of diving to 226 m depth and to the deepest area of depth habitat (Westgate et al. 1995). Based on information primarily from the Otani et al. (1998) study, the depth distribution for harbor porpoises can be estimated as 75% at 0-20 m, 15% at 21-40 m, and 10% at >40 m.

A.7 CARNIVORES - PINNIPEDS

Northern Fur Seal – QUTR Site

The northern fur seal is endemic to the north Pacific. Breeding sites are located in the Pribilof Islands (up to 70% of the world population) and Bogoslof Island in the Bering Sea, Kuril and Commander Islands in the northwest Pacific, and San Miguel Island in the southern California Bight. Abundance of the Eastern Pacific Stock has been decreasing at the Pribilof Islands since the 1940s although increasing on Bogoslof Island. The stock is currently estimated to number 721,935 (NMFS 2006a). The San Miguel Island stock is much smaller, estimated at 7,784 (Carretta et al. 2007); this stock is believed to remain predominantly offshore California year round.

Males are present in the Pribilof Island rookeries from around mid-May until August; females are present in the rookeries from mid-June to late-October. Nearly all fur seals from the Pribilof Island rookeries are foraging at sea from fall through late spring. Females and young males migrate through the Gulf of Alaska and feed primarily off the coasts of British Columbia, Washington, Oregon and California before migrating north again to the rookeries (Ream et al. 2005); there were several northern fur seal sightings in the OCNMS region during June 2005 vessel surveys. Immature males and females may remain in southern foraging areas year round until they are old enough to mate (NMFS 2006a). Adult males migrate only as far south as the Gulf of Alaska or to the west off the Kuril Islands. Therefore, adult female (November-April) and all non-adult fur seals (year round) can potentially be found offshore Washington depending on the time of year.

To determine fur seal density for the area off Washington, geographic area and number of seals need to be determined. The geographic area was defined as the large region offshore California, Oregon, Washington and British Columbia as this is where fur seals forage. This area, based on Figure 4 in NMFS (2006a), was estimated via ArcMap as 6,165,000 km2 (Figure A-5).

To determine the number of fur seals in this area from November-May, adult females plus non-breeding immature males and females from the Eastern North Pacific Stock (711,957; NMFS 2006a) needed to be added to the entire stock from San Miguel Island (7,784; Carretta et al. 2007) for a total of 719,741; adult males (9,978; NMFS 2006a) from the Pribilof Islands were excluded as they forage in the Gulf of Alaska. Density was then calculated as 719,741 fur seals/6,165,000 km2, or 0.117/km2 (Table A-1). This density is applicable for the QUTR Site for November-May.

To determine density for the rest of the year (June-October) when only immature non-breeding fur seals would be present (adult breeding seals would be returning to the rookeries), the same geographic area was used. The number of animals was adjusted to remove adult females. The 2005 census of pups in the Pribilof Islands yielded 160,430 pups (NMFS 2006a), therefore the same number of adult females are assumed. In the San Miguel Island stock, 2,356 pups were counted in 2005 (Carretta et al. 2007). Total number of adult females, therefore, was 162,786 which, when subtracted from the total determined above (719,741) results in 556,955 fur seals. Density of immature fur seals from June-October was

556,955/6,165,000 km^2 or 0.090/ km^2 (Table A-1), which is applicable for the QUTR Site. Northern fur seals are rarely sighted in Puget Sound; density for the DBRC and Keyport Range sites is zero for all months.

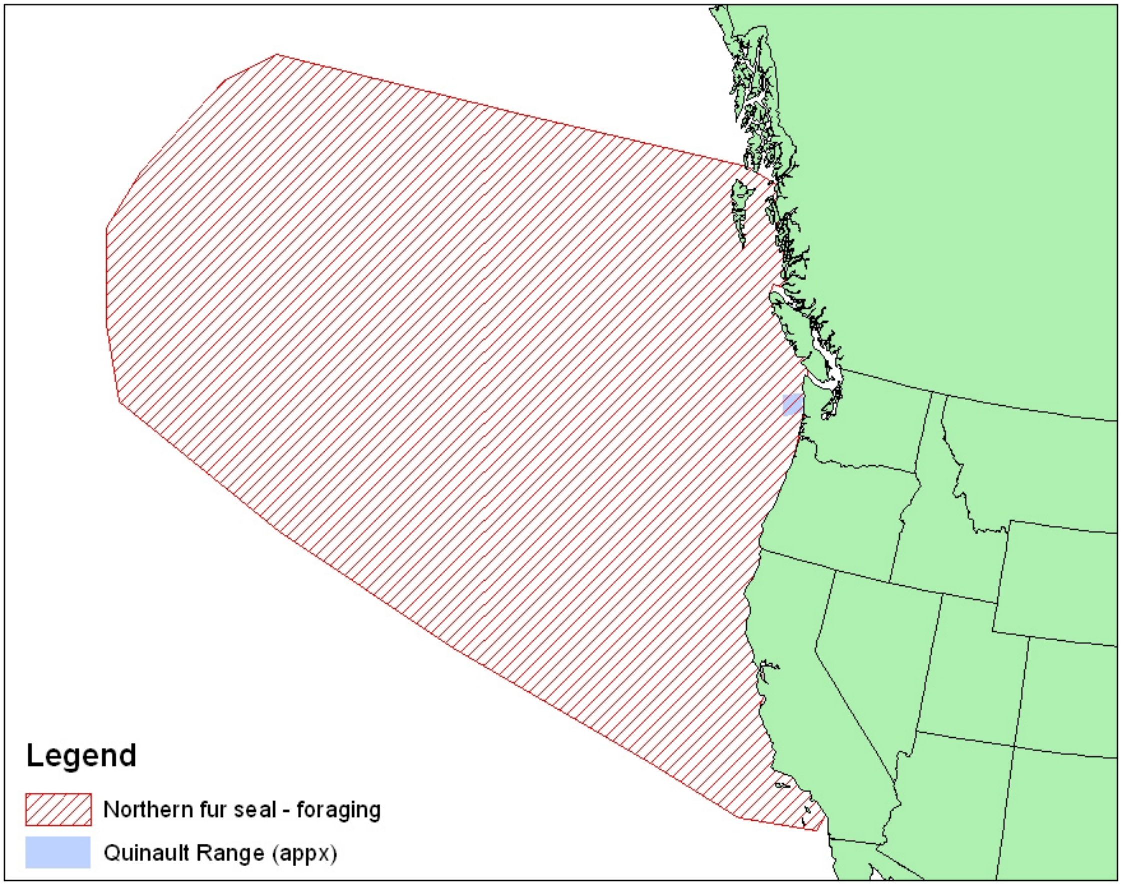

Figure A-5. Area of Northern Fur Seal Foraging Distribution Used to Calculate Density

Northern fur seals feed on small fish and squid in deep water and along the shelf break; deep dives occur on the shelf and feeding probably occurs near the bottom (Gentry 2002). There have been a few studies of this species' diving habits during feeding and migration, although there is no information on dive depth distribution. Ponganis et al. (1992) identified two types of northern fur seal dives, shallow (<75 m) and deep (>75 m). Kooyman and Goebel (1986) found that the mean dive depth for seven tagged females was 68 m (range 32-150 m) and the mean maximum depth was 168 m (range 86-207 m). Sterling and Ream (2004) reported that the mean dive depth for 19 juvenile males was 17.5 m, with a maximum depth attained of 175 m. Diving was deeper in the daytime than during nighttime, perhaps reflecting the different distribution of prey (especially juvenile pollock), and also differed between inner-shelf, mid-shelf, outer-shelf and off-shelf locations. Deeper diving in the Sterling and Ream study tended to occur on-shelf, with shallower diving off-shelf. Based on these very limited depth data, the following are very rough order estimates of time at depth: daytime: 100% at 0-210 m; nighttime: 100% at 0-75 m.

Steller Sea Lion – QUTR Site

The range of the Steller sea lion (SSL) crosses the north Pacific from Japan to northern California. This species does not undergo extensive migrations but will disperse widely during the non-breeding season. There are two US stocks, which are delineated based on the location of rookeries. The eastern US stock, listed as Threatened, includes SSL whose rookeries are east of 144˚W and extend down the west coast of North America. The current population estimate for the eastern US stock, based on pup counts conducted in 2005, is 47,885 (Angliss and Outlaw 2007). There are no SSL rookeries in Washington. The closest major rookery in Oregon is Three Arch Rock-Seal Rock and the closest major rookeries in British Columbia are on Triangle, Sartine and Beresford Islands at the north end of Vancouver Island (NMFS 2006b). SSL numbers in Washington vary seasonally, with peak counts at haulouts occurring during fall and winter. Jeffries et al. (2000) identified 21 haulout locations for SSL along the coast and inland waterways of Washington, including four in the Split Rock area (47.40N, 124.35W); animals at these haulout locations are assumed to be immatures and non-breeding adults associated with rookeries in Oregon and British Columbia (Pitcher et al. 2007). Steller sea lions are not known to haulout in Hood Canal. Most SSL remain fairly close to rookeries and haulouts throughout the year, with adult females with pups averaging 17 km trip length in summer and 130 km trip length in winter; however, foraging trips extended to >500 km offshore (Loughlin 2002; Merrick and Loughlin 1997). Foraging trips are interspersed with time spent at haulouts throughout the year, and different age and sex classes molt at different times from late summer through early winter. Consequently, at any particular time during the year, at least some portion of the population will be at-sea. Bonnell and Bowlby (1992) estimated that 25% of the SSL population was feeding at sea at any given time. Call et al. (2007) found that the duration of at-sea and on-shore cycles of juvenile SSL differed between regions. In the Aleutian Islands and Gulf of Alaska, juvenile SSL departed at dusk and returned to haul out just prior to sunrise, while juvenile SSL in southeast Alaska departed throughout the day. Time of day departures and length of time at-sea are likely related to foraging opportunities and the distance/depth required for juveniles to travel finding food.

To determine densities of SSL off Washington State, two parameters needed to be identified – the specific area and the number of animals. The area for the Eastern US stock of SSL, taken from Figure I-1 in NMFS (2006b), was estimated as ~1,244,000 km2 via ArcMap (Figure A-6). The population estimate for the eastern US population (47,885) was multiplied by 25% for a total of 11,971. Density, therefore, was estimated as 11,971 SSL/1,244,000 km2, or 0.0096/km2 (Table A-1), which is applicable to the QUTR Site year round. Steller sea lions are occasionally seen in Puget Sound, but their occurrence is generally rare; density is zero for the DBRC and Keyport Range sites for all months.

Steller sea lions feed on fishes and invertebrates, including walleye pollock, Pacific cod, mackerel, octopus, squid and herring (Loughlin 2002). Ongoing studies of SSL diving behavior have been conducted by NMFS in Alaska and Washington as part of an overall effort to determine why sea lion populations have been steadily declining (Merrick and Loughlin 1997; Loughlin et al. 2003). Tagging studies often focus on different age classes (weanling, young of year, adult female). Steller sea lion prey changes depending on the season, with some prey moving farther offshore in winter, which affects maximum depth. Females dived the longest and deepest, with young of the year and weanlings having lesser values for both categories. Because all age classes may be in the water at any given time, the depth distribution was estimated from the proportion of dives per depth range for all age classes (Merrick and Loughlin 1997; Figures 4 and 2, respectively). Based on this information, the depth distribution can be roughly estimated at 60% at 0-10 m, 22% at 11-20 m, 12% at 21-50 m, 5% at 51-100 m and 1% at >100 m.

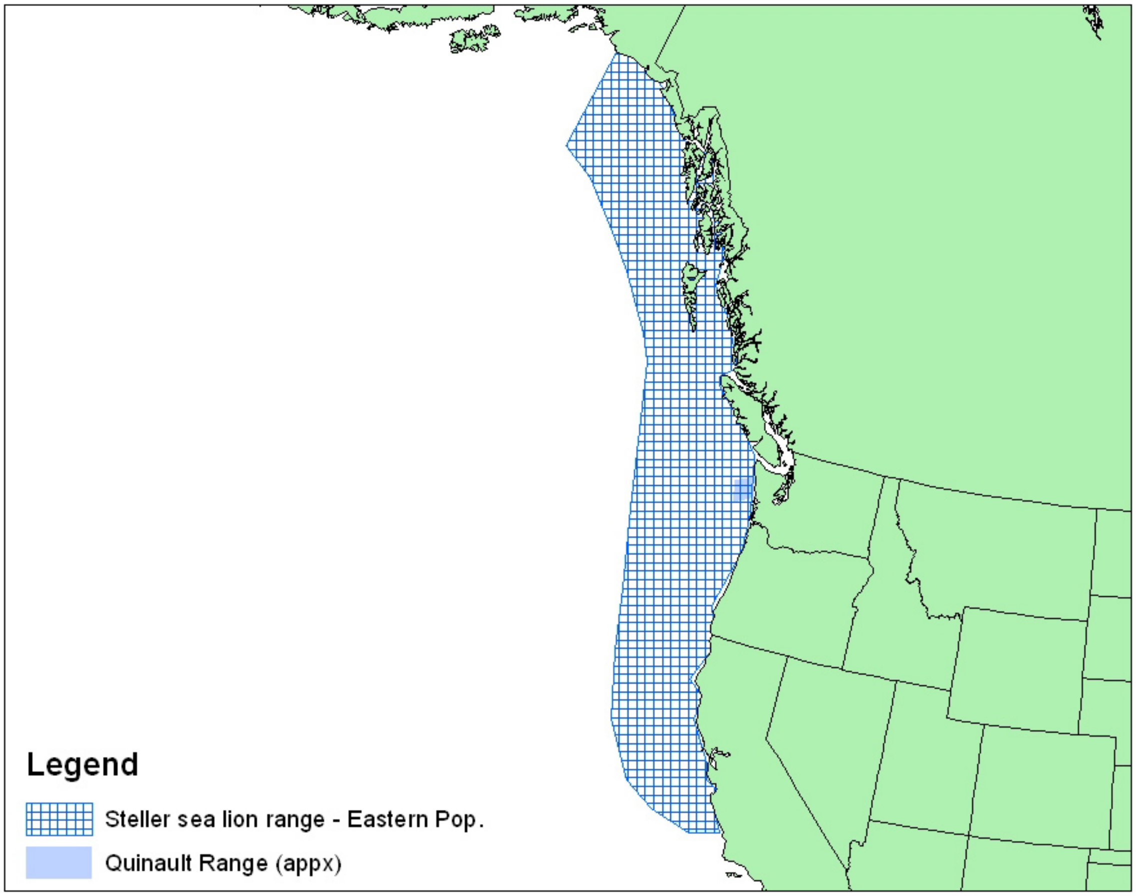

Figure A-6. Area of Steller Sea Lion Eastern US population Range Used to Calculate Density

<u>California Sea Lion – QUTR and DBRC Sites</u>

The US stock of California sea lions breeds in the Channel Islands in the southern California Bight. The population is currently estimated at 237,000 to 244,000, based on pup counts conducted in 2001 (Carretta et al. 2007). There are two additional stocks of California sea lions; one breeds on islands off the west coast of Baja California, while the other breeds on islands in the Gulf of California. There is some mixing between all three stocks during the non-breeding season, although the extent is unknown. Pupping and breeding occur from May-July. Females generally do not migrate as far north as males, remaining closer to the rookeries. Adult male California sea lions will migrate north after the breeding season (August-April) to nearshore waters of Washington, Oregon and British Columbia, and a few immature males will remain in northern feeding areas year round. Jeffries et al. (2000) identified 46 haulout locations used by California sea lions along the Washington/southern British Columbia coast and inland waterways. Most haulouts were in southern Puget Sound, with two large (100-500 animals each) haulouts located along the outer coast in the Split Rock area. California sea lions feed near the mainland coast and around seamounts; in Washington, males position themselves near river and stream mouths to take advantage of fish migrations.

As with other pinniped species, geographic area and number of animals need to be identified to determine density. Geographic area was approximated from the 14 haulout regions delineated by Jeffries et al. (2000) in the Atlas of Pinniped Haulout Sites (Figure A-7). This area was estimated as ~17,650 km^2 via

ArcMap. California sea lions do not use haulouts in all 14 of the regions, however, they would be traversing many of the areas during migration or foraging. Jeffries et al. (2000) estimated that peak numbers of 3,000 to 5,000 California sea lions migrate into northwest numbers from fall until late spring. Density, therefore, was estimated as 5,000/17,650 km^2, or 0.283/km^2 (Table A-1). This density is applicable only to the very nearshore waters of Washington State, which represents 6% (414 km^2/ 7,063 km^2) of the QUTR Site (see Figure A-34 for depiction of this area), from August to April.

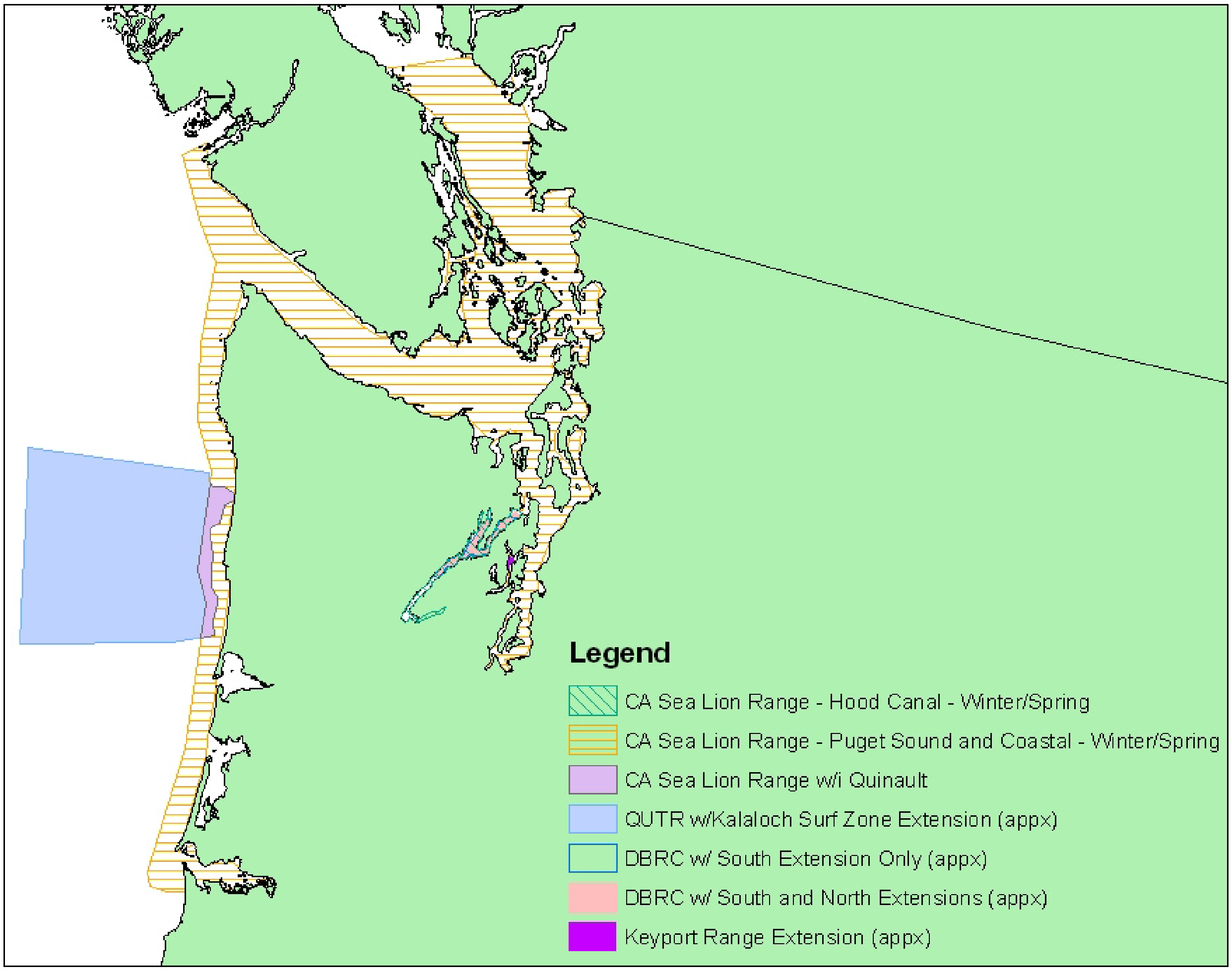

Figure A-7. Area of California sea lion range used to calculate densities, and area of Quinault range for which density is applicable. Only the Kalaloch Surf Zone extension is shown.

Jeffries et al. (2000) did not identify any California sea lion haulouts within Hood Canal, but five navigational buoys near the entrance to Hood Canal were documented as haulouts; navigational buoys are large enough to hold approximately three adult male California sea lions at any one time. California sea lions are also commonly seen in the vicinity of the Bangor Subase (Department of the Navy 2001). To determine density of California sea lions for the DBRC Site, the maximum number of sea lions per buoy (3) was multiplied by the number of buoys used by California sea lions near Hood Canal (5), then divided by the size of Hood Canal as determined via ArcMap (291 km^2) for a density of 0.052/ km^2. This density is likely conservative, as the likelihood that all 15 sea lions would be in the water at one time is remote. This density applies to the DBRC Site for from August-April.

California sea lions are rarely seen near Keyport; density is zero for the Keyport Range Site for all months.

California sea lions feed on a wide assortment of fish, including anchovy, whiting, rockfish and mackerel, as well as cephalopods; diet depends on season, location and oceanographic conditions (Heath 2002). There have been limited dive data collected on California sea lions. Feldkamp et al. (1989) tagged ten female sea lions on San Miguel Island during the breeding season. The deepest dive recorded was estimated at 274 m but most dives were <80 m (with the majority between 20 and 60 m; see Figure 4 in Feldkamp et al. 1989). Less than 5% of all dives were >200 m. Peak diving frequency occurred near sunrise and sunset, but diving was recorded during all hours. Activity patterns showed that ~33% of total time was spent diving, ~41% was spent swimming between dive bouts, ~23% of the time was at the surface during dive bouts, and 3% was spent resting. Seasonal and daily diving patterns suggested that prey presence strongly influences depth and duration of dives. Based on this information, California sea lion depth distribution can be roughly estimated at 26% at <2 m (surface), 41% at 2-10 m (swimming between dive bouts), 3% at 11-19 m, 17% at 20-60 m and 13% at >60 m.

Northern Elephant Seal – QUTR Site

The California stock of elephant seals breeds at rookeries located along the California coast; breeding season is December through February (Reeves et al. 2002). The most recent population estimate (2001) was 101,000 animals and was based primarily on pup counts (Carretta et al. 2007). Except during breeding season and annual molt, elephant seals remain largely at-sea and rarely haulout for long periods of time. Adult male elephant seals migrate north via the California current to the Gulf of Alaska during foraging trips, and could potentially be passing through the area offshore Washington in May and August (migrating to and from molting periods) and November and February (migrating to and from breeding periods), but likely their presence there is transient and short-lived. Elephant seals seen at Washington State haulouts have been mostly solitary adult males (Jeffries et al. 2000); known haulouts are along the outer coast and the Strait of Juan de Fuca. Adult females and juveniles forage in the California current offshore California to British Columbia (LeBoeuf et al. 1986, 1993, 2000). Pups remain onshore for up to 3 months after birth before they venture offshore. Females and juveniles return to rookeries and haulouts to molt from March through July. Molting takes about three weeks and is a long protracted population event as different age and sex classes tend to molt at the same time.

Estimating density for elephant seals requires an estimate of geographic area and an estimate of the population that would be in that area at any given time. Geographic area was estimated, via ArcMap, as 2,032,000 km2 (Figure A-8), based on a figure of female foraging range provided in Reeves et al. (2002). During the breeding period (December-February), offshore occurrence would be limited to immature (non-breeding) seals. The number of immature seals was estimated by subtracting the estimated number of adult males, females and pups from the total estimated population. The most recent pup counts (Carretta et al. 2007) yielded 28,845 pups, which extrapolate to 28,845 adult females. Lowry (2002) estimated 2,300 males at rookeries in the Channel Islands in 2001, and 523 males were estimated at the Anõ Nuevo rookery the same year. There were several rookeries not included in this estimate, including a rapidly growing rookery at Piedras Blancas, which in 2007 had an estimated population of 16,000 animals of all age and sex classes (www.elephantseal.org). The California elephant seal population has also been steadily increasing over time (Carretta et al. 2007). To account for males at rookeries not counted and an increase in the population since 2001, the number of males reported in the 2007 stock assessment report (2,840) was doubled to 5,680. Assuming a total estimate of 101,000 seals, and subtracting the number of adult males (5,680), adult females (28,845) and pups (28,845), the density for December-February was calculated as 37,630 seals/2,032,000 km^2, or 0.019/km^2 (Table 1), which applies to the entire QUTR Site.

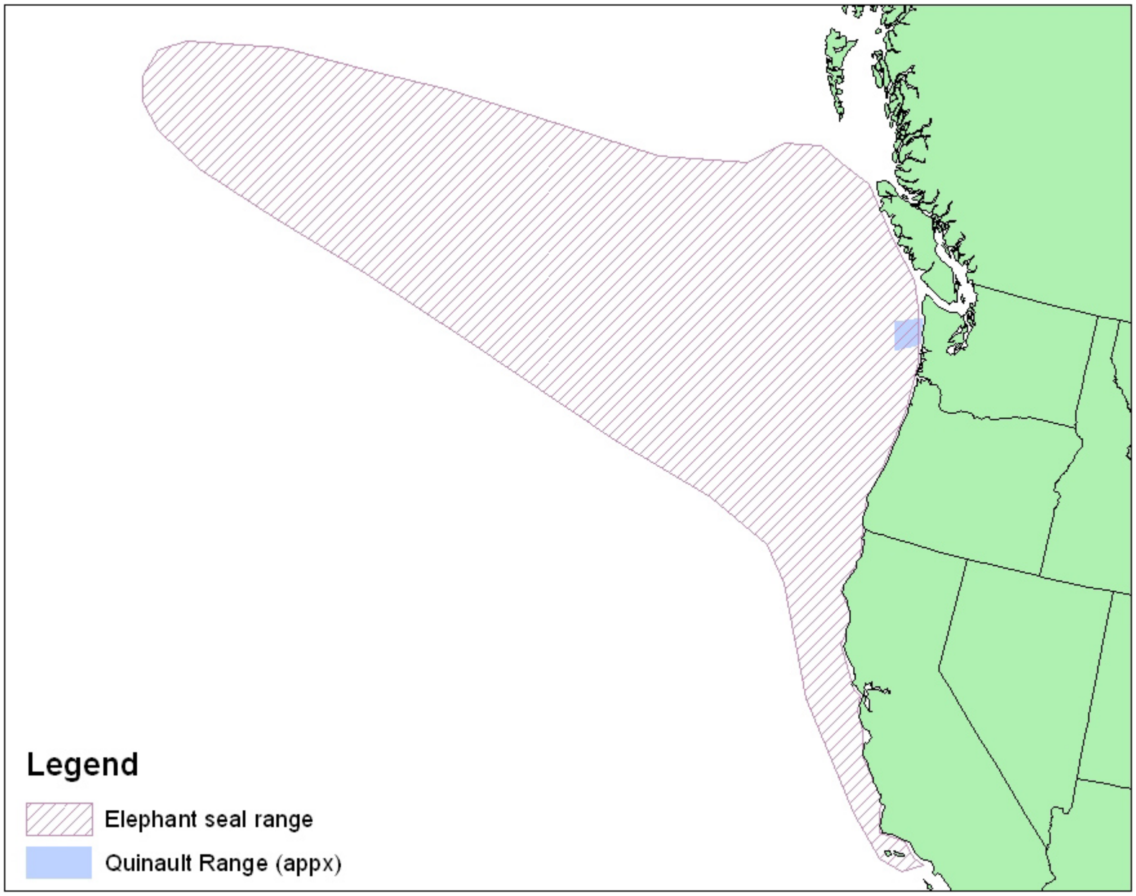

Figure A-8. Area of Elephant Seal Range Used to Calculate Density

Following the breeding season, most seals are at-sea foraging, but some juveniles are returning to rookeries to molt. Molting of all age and sex classes occurs over a roughly 15-week period from Mar-Jul, so we have assumed that approximately 80% of the adult females and juveniles are foraging at any one time. In March and April, offshore occurrence would include females (28,845) and juveniles (37,630) only (pups have not yet left the rookeries and adult males have migrated farther north to the Gulf of Alaska); 80% of that total is 53,180. Therefore, density in the QUTR Site in March-April would be 53,180/2,032,000km^2, or 0.026/km^2 (Table A-1). In May-July, offshore occurrence would include adult females, juveniles and pups of the year for a total of 95,320; 80% of that total would be 76,256. Therefore, density in the QUTR Site in May-July would be 76,256/2,032,000 km2, or 0.038/km2 (Table A-1). In August-November, offshore occurrence would include all elephant seals except adult males, and there is no molting taking place so the estimated abundance offshore would be 95,320. Therefore, density in the QUTR Site in August-November would be 95,320/2,032,000 km2, or 0.047/km2 (Table A-1).

Elephant seals are rarely seen in Puget Sound; the closest documented haulout is on Dungeness Spit in the Strait of Juan de Fuca (Jeffries et al. 2000). Density is zero for the DBRC and Keyport Range sites.

Elephant seals feed on deep-water squid and fish, and likely spend about 80% of their annual cycle at sea feeding (Hindell 2002). There has been a disproportionate amount of research done in the diving capabilities of northern elephant seals. Breeding and molting beaches are all located in California and Baja California. Elephant seals are relatively easy to tag (compared to cetaceans) when they are hauled out on the beach and the tag package can be retrieved when the animal returns to shore rather than relying on finding it in the ocean. They are deep divers, and have been tracked to depths >1000 m, although mean depths are usually around 400-600 m. Elephant seals have more than one dive type, termed Types A-E, including rounded and squared-off U-shape, V-shape and others. Particular dive types appear to be used mainly during transit (Types AB), "processing" of food (Type C), and foraging (Types DE) (Crocker et al. 1994). Asaga et al. (1994) collected dive information on three female seals and provided summary statistics for three dive types. Davis et al. (2001) recorded the diving behavior of a seal returning to the beach, and illustrated transit depth averaging 186 m with range of depth from 8 m to 430 m. LeBoeuf et al. (1986; 1988), Stewart and DeLong (1993) and LeBoeuf (1994) provided histograms of dives per depth range for tagged females. LeBoeuf et al. (2000, 1988) and LeBoeuf (1994) provided details on foraging trips for males and females offshore California, including information on percentage of time at surface. Hassrick et al. (2007) noted that larger animals (adult males) exhibited longer bottom times and that surface swimming was not noted in the sixteen elephant seals that they tagged. Hindell (2002) noted that traveling likely takes place at depths >200m.

Even with this abundance of information, the numerous types of dives and lack of clear-cut depth distribution data means that the percentage of time at depth needs to be estimated. The closest information provided is from Asaga et al. (1994), which was used here. Note that this information is representative of type D foraging dives of females only. This is the type of dive that would be likely of an elephant seal at-sea. Summary statistics from Table 17.3 (Asaga et al. 1994) were used; the data were collected from females only but will be applied to both sexes and all age classes due to lack of other data. Mean dive duration and mean surface intervals were added together to yield total dive cycle in minutes. Amount of time to traverse from surface to bottom and bottom to surface was calculated by subtracting bottom time (given) from dive duration. Values for total cycle, surface interval, bottom time and descent/ascent were then averaged for all three females. Roundtrip surface to bottom and back averaged 12.9 minutes. Assuming a mean rate of descent/ascent over 527 m (average mean dive depth for all three females combined), the average rate per 100 m was 2.4 min. Based on these averaged numbers, the following are estimates of time at depth: 9% at <2 m, 11% at 2-100 m, 11% at 101-200 m, 11% at 201-300 m, 11% at 301-400 m, 11% at 401-500 m and 36% at >500 m.

<u>Harbor Seal – QUTR, DBRC, and Keyport Range Sites</u>

Harbor seals are found largely in coastal areas of the north Pacific and north Atlantic (Reeves et al. 2002). Most are non-migratory, and breed and feed in the same area throughout the year. This is the only pinniped species that breeds in Washington State. Jeffries et al. (2000) documented several harbor seal rookeries and haulouts along the Washington coastline and inland waterways. Two different stocks of harbor seals are recognized for the waters of Washington State. The most recent estimate for the Oregon/Washington Coastal stock, based on counts of hauled out seals including pups and conducted in 1999, was 24,732 (Carretta et al. 2007). The 1999 count of harbor seals along the outer Olympic Peninsula region alone was 7,117 (Jeffries et al. 2003) which, when adjusted by a correction factor of 1.53 to account for seals in the water (and not counted), provides an estimate for that region of 10,889. The correction factor of 1.53 (from Huber et al. 2001) indicates that approximately 35% of harbor seals are in the water at any given time (7,117 counted on land/10,889 total = 65% on land). Therefore, the estimated number of harbor seals on the Olympic Coast in the water is 3,811. The geographic area for this stock, estimated via ArcMap (Figure A-9), is 8,630 km^2. Therefore, the density of harbor seals year round in the waters of the QUTR Site was estimated as 0.44/km^2 (Table A-1); this density is applicable to nearshore (<50 km) areas only, which represents 52% (3,656 km^2/ 7,063 km^2) of the QUTR Site (see Figure A-9 for depiction of this area).

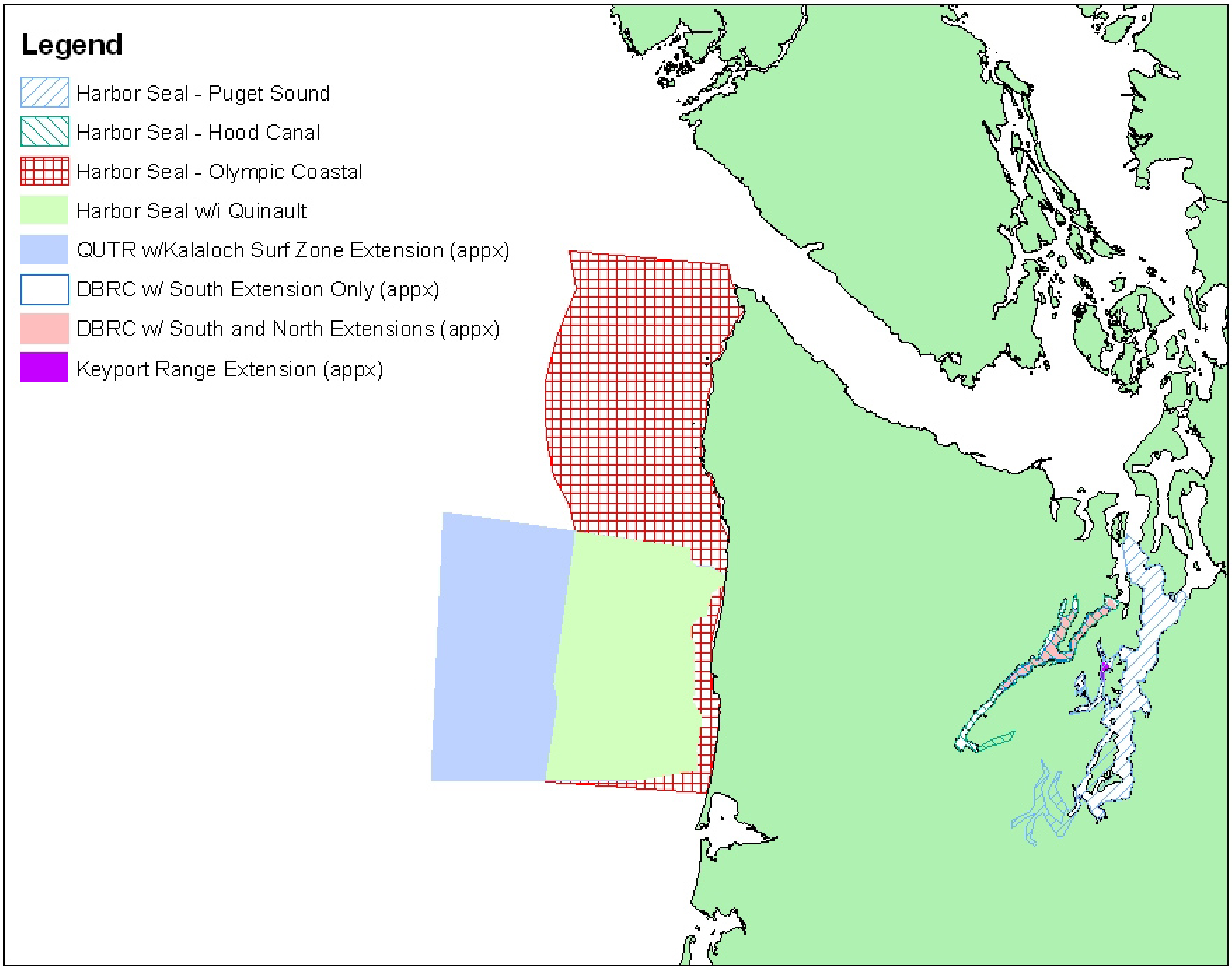

Figure A-9. Area of Harbor Seal Ranges Used to Calculate Density, and Area of QUTR Site for Which Density is Applicable (Note that the area for Puget Sound harbor seals did not include Vashon Island even though the hatching extends across the island)

The Washington Inland Waters stock inhabits waters of Puget Sound, Hood Canal and Strait of Juan de Fuca out to Cape Flattery, and the most recent (1999) abundance estimate for the entire area (1999) was 14,612 (Carretta et al. 2007). The 1999 count of harbor seals for the Hood Canal region (including the Dabob Bay area) was 711 (Jeffries et al. 2003) which, when adjusted by a correction factor of 1.53 to account for seals in the water and not counted, provides an estimate for Hood Canal of 1,088. Assuming that only 35% of the seals are in the water at any given time, based on the assumptions outlined above, the estimated number of harbor seals in Hood Canal in the water is 381. The geographic area for this stock, estimated via ArcMap (Figure A-9), is 291 km2. Therefore, the density of harbor seals year round in the waters of the Dabob Bay range was estimated as 1.31/km2 (Table A-1) which is applicable to the entire range. There are several harbor seal haulouts in Hood Canal (Jeffries et al. 2000). In 2003 and 2005, transient killer whales were observed in Hood Canal for extended periods of time (>59 days each year) feeding on harbor seals. London (2006) estimated via bio-energetic models and vessel-based observations that harbor seal consumption by killer whales was significant. "However, aerial surveys conducted following the two foraging events have not detected a significant decline in the harbor seal population." (London 2006).

Harbor seals are seen regularly in the Keyport area, despite no nearby documented haulouts (the closest haulout is north near Poulsbo; Jeffries et al. 2000). The 1999 count of harbor seals for the Puget Sound (including the Keyport area) was 1,025 (Jeffries et al. 2003) which, when adjusted by a correction factor of 1.53 provides an estimate for Puget Sound of 1,568. Assuming that only 35% of the seals are in the water at any given time, the estimated number of harbor seals in Puget Sound in the water is 549. The geographic area for this stock, estimated via ArcMap (Figure A-9), is 994 km2. Therefore, the density of harbor seals year round in the waters of the Keyport range was estimated as 0.55/km2 (Table A-1).

Studies of harbor seal diving behavior have been conducted in several locations on various age, physiological and sex classes. Harbor seals feed on fish, octopus, squid, shrimp and other available prey (Reeves et al. 2002), and have been observed eating Pacific herring and salmon in Washington inland waters (Suryan and Harvey 1998). They make mostly U-shaped (or square) dives when foraging, but also V-shaped, "wiggle", and skewed dives (Baechler et al. 2002), and may spend ~85% of the day diving for food (Reeves et al. 2002). Bowen et al. (1999) found that lactating females from Sable Island, Nova Scotia, spent 45% of time on land with their pups, 55% of time at sea and only 9% of the total time actively diving, indicating that there is widespread variation within the species. Bowen et al. (1999) also determined that about half of the total dive time was spent at the bottom of the dive. Eguchi and Harvey (2005) found that median depth and duration of dive were positively correlated with body mass, and large adult males generally dove deeper and longer than the smaller adult females. Approximately 80% of the dives recorded by Eguchi and Harvey (2005) of harbor seals in Monterey Bay, California, were U-shaped, and most of those were <100 m (mean 51.9 m for males; 39.8 m for females). The deepest dive was 481 m. Foraging dive bouts consisting of several rapidly occurring U-shaped dives were separated from one another by equally long bouts of non-foraging dives to <3 m (see Eguchi and Harvey 2005; Figure 2). Approximately 50% of total time was spent at the surface in non-foraging mode. Based largely on the information from Eguchi and Harvey (2005), the following are estimated time at depth for harbor seals: 50% at <3 m, 20% at 3-50 m, 25% at 51-100 m and 5% at >100 m.

A.8 CARNIVORES – SEA OTTER

Sea Otter – QUTR Site

Sea otters were exterminated from the Washington coast via hunting by the early 1900s, and were reintroduced in 1969 and 1970 via transplantation from otter populations in Alaska. The reintroduced population has been increasing annually at an average rate of 8.2% (Lance et al. 2004); the latest published count based on intensive aerial surveys conducted in 2005 is 814 (Jameson and Jeffries 2005). Sea otter range in Washington extends from just south of Destruction Island to Pillar Point in the Strait of Juan de Fuca. North of La Push the rate of annual increase is ~3.5% and the population may be reaching density equilibrium. However, south of LaPush, the annual rate of increase is ~20%, and a greater proportion of sea otters are found in that area (Jameson and Jeffries 2005). Occasionally individuals are seen within Puget Sound, but occurrence is very rare (Lance et al. 2004). Sea otters are entirely marine and rarely venture onto land; birthing and nursing take place in coastal waters and there is no seasonal molt. They remain in extreme nearshore waters, within 2 km of shore and usually less than 37 m depth (Lance et al. 2004). They are capable of ranging widely along the coast, and may shift distribution seasonally in response to food availability or storm events. Density (animals per km of coast) was provided for 2004 for each of three coastal segments. The density for the southern segment from Quillayute Needles to south of Destruction Island (Figure A-10) was 16.1 (410 otters/25.5 km) (Lance et al. 2004; Table 6). Using the 2005 count for the south segment (437) and area instead of coastline distance (25.5 km * 2 km = 51 km), density for sea otters year round would be 8.57 otters/km^2 (Table A-1). Sea otter distribution would not extend far enough offshore to occur in the QUTR Site so density for QUTR is zero. Density is also zero for the DBRC and Keyport Range sites.

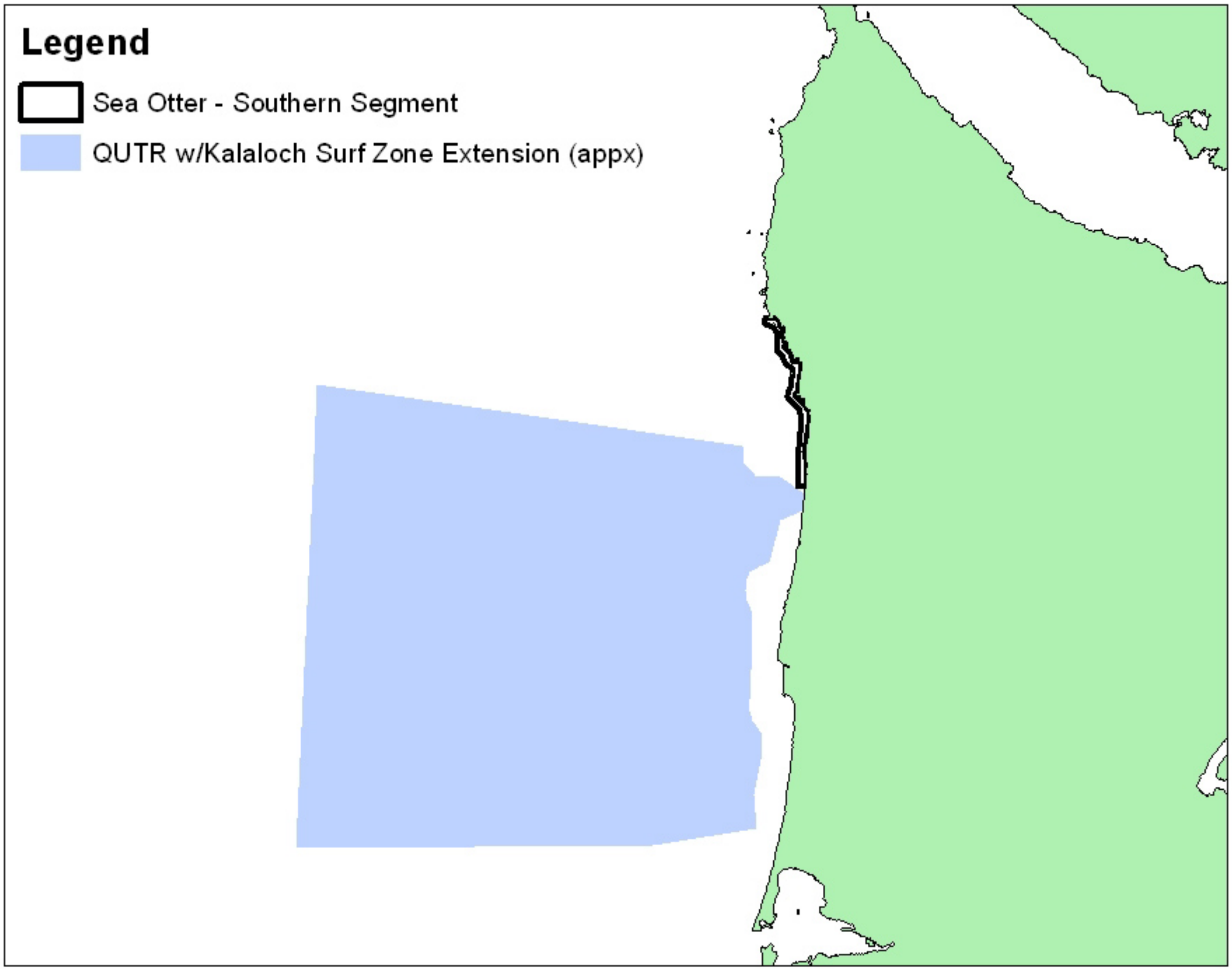

Figure A-10. Area of Sea Otter Southern Segment Range Used to Calculate Density. Note that distribution does not overlap that of the QUTR Site.

Table A-3: Summary of Marine Mammal Depth and Diving Information for Species Found in the NAVSEA NUWC Keyport Range Complex

NOTE: Some species that are not endemic to the Pacific Northwest are included because data on their depth and diving preferences were extrapolated to Washington species.

GENERAL INFORMATION				**DEPTH SPECIFIC INFORMATION**					
Common Name	**Food Preference**	**Depth or Oceanic Preference**	**References**	**Behavioral State**	**Geographic Region**	**Depth Information**	**Depth Distribution**	**Sample Size/ Time of Year/Method**	**References**
MYSTICETES - Baleen whales									
Blue whale	Euphausiid crustaceans, including *Euphausia* sp and *Thysanoessa* sp	Coastal as well as offshore	Sears (2002); Croll et al. (2001); Acevedo et al. (2002); Bannister (2002)	Feeding at depth	Northeast Pacific (Mexico, California)	Mean depth 140 +- 46 m; mean dive time 7.8 +- 1.9 min		Seven whales/ May-August/Time-depth-recorder	Croll et al. (2001)
Blue whale				Feeding near surface; surface intervals between deeper dives	Northeast Pacific (central California)	Mean depth 105 +- 13 m; mean dive time 5.8 +- 1.5 min	78% in 0-16 m; 9% in 17-32; 13% in >32 m; most dives to <16 m and 96-152 m ranges, but only 1.2% of total time was spent in deeper range	One whale/ August-September/ Satellite depth-sensor-tag	Lagerquist et al. (2000)
Blue whale				Non-feeding	Northeast Pacific (Mexico, California)	Mean depth 68 +- 51 m; mean dive time 4.9 +- 2.5 min; most dives to ~30 m with occasional deeper V-shaped dives to >100m		Seven whales/ May-August/Time-depth-recorder	Croll et al. (2001)
Fin whale	Planktonic crustaceans, including *Thyanoessa* sp and *Calanus* sp, as well as scholling fishes such as capelin (*Mallotus*), herring (*Clupea*) and mackerel (*Scomber*)	Pelagic with some occurrence over continental shelf areas, including in island wake areas of Bay of Fundy	Aguilar (2002); Croll et al. (2001); Acevedo et al. (2002): Notarbartolo-di-Sciara et al. (2003); Bannister (2002); Johnston et al. (2005); Watkins and Schevill (1979)	Feeding at depth	Northeast Pacific (Mexico, California)	Mean depth 98 +- 33 m; mean dive time 6.3+- 1.5 min		Fifteen whales/ April-October/Time-depth-recorder	Croll et al. (2001)

GENERAL INFORMATION					DEPTH SPECIFIC INFORMATION					
Common Name	Food Preference	Depth or Oceanic Preference	References		Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/ Time of Year/Method	References
Fin whale					Non-feeding	Northeast Pacific (Mexico, California)	Mean depth 59 +-30 m; mean dive time 4.2 +-1.7 min; most dives to ~ 30 m with occasional deeper V-shaped dives to >90 m		Fifteen whales/ April-October/Time-depth-recorder	Croll et al. (2001)
Fin whale					Feeding	Mediterranean (Ligurian Sea)	Shallow dives (mean 26-33 m, with all <100m) until late afternoon; then dives in excess of 400 m (perhaps to 540 m); in one case a whale showed deep diving in midday; deeper dives probably were to feed on specific prey (*Meganyctiphanes norvegica*) that undergo diel vertical migration		Three whales/ Summer/ Velocity-time-depth-recorder	Panigada et al. (1999); Panigada et al. (2003); Panigada et al. (2006)
Fin whale					Traveling	Mediterranean (Ligurian Sea)	Shallow dives (mean 9.8 +- 5.3 m, with max 20 m) , shorter dive times and slower swimming speed indicate travel mode; deep dives (mean 181.3 +-195.4 m, max 474 m), longer dive times and faster swimming speeds indicate feeding mode		One whale/ Summer/ Velocity-time-depth-recorder	Jahoda et al. (1999)

GENERAL INFORMATION					DEPTH SPECIFIC INFORMATION					
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Fin whale					Feeding	Northeast Pacific (Southern California Bight)	Mean dive depth 248+-18 m; total dive duration mean 7.0+-1.0 min with mean descent of 1.7+-0.4 min and mean ascent of 1.4+-0.3 min; 60% (i.e., 7.0 min) of total time spent diving with 40% (i.e., 4.7 min) total time spent near sea surface (<50m)	44% in 0-49m (includes surface time plus descent and ascent to 49 m); 23% in 50-225 m (includes descent and ascent times minus time spent descending and ascending through 0-49 m); 33% at >225 m (total dive duration minus surface, descent and ascent times)	Seven whales/ August/ Bioacoustic probe	Goldbogen et al. (2006)
Fin whale					Feeding	Northeast Pacific (Southern California Bight)	Distribution of foraging dives mirrored distribution of krill in water column, with peaks at 75 and 200-250 m.		Two whales/ September-October/ Time-depth-recorder	Croll et al. (2001)
Sei whale	Copepods, amphipods, euphausiids, shoaling fish and squid	More open ocean than coastal, but occasionally move close to shore to opportunistically feed	Horwood (2002); Jefferson et al. (1993); Nemoto and Kawamura (1977); Bannister (2002); Watkins and Schevill (1979); Clarke (1986)		Feeding	Northwest Pacific - coastal	Skim feeder that takes swarms in low density		Several/ Year-round/ Stomach content analysis	Nemoto and Kawamura (1977)
Sei whale					Feeding	Northern Atlantic (southern Gulf of Maine)	Lunge-feeding just below surface, surface skim feeding, gulping; likely feeding on krill		29 animals/ July-September/ visual observations	Weinrich et al. (1986)

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Minke whale	Regionally dependent; can include euphausiids, copepods, small fish and squids; Japanese anchovy preferred in western North Pacific, capelin and krill in the Barents Sea; armhook squids in North Pacific	Coastal, inshore and offshore; known to concentrate in areas of highest prey density, including during flood tides	Perrin and Brownell (2002); Jefferson et al. (1993); Murase et al. (2007); Bannister (2002); Lindstrom and Haug (2001); Johnston et al. (2005); Hoelzel et al. (1989); Haug et al. (2002); Haug et al. (1995); Haug et al. (1996); Konishi and Tamura (2007); Clarke (1986)		Feeding, Searching	North Atlantic (Norway)	Searching for capelin at less than 20 m, then lunge-feeding at depths from 15 to 55 m, then searching again at shallower depths	Based on time series, 47% of time was spent foraging from 21-55 m; 53% of time was spent searching for food from 0-20 m	One whale/ August/ Dive-depth-transmitters	Blix and Folkow (1995)
Minke whale					Feeding	North Pacific (San Juan Islands)	80% of feeding occurred over depths of 20-100m; two types of feeding observed both near surface - lunge feeding and bird association		23 whales/ June-September/ behavioral observations	Hoelzel et al. (1989)
Humpback whale	Pelagic schooling euphausiids and small fish including capelin, herring, mackerel, croaker, spot, and weakfish	Coastal, inshore, near islands and reefs, migration through pelagic waters	Clapham (2002); Hain et al. (1995); Laerm et al. (1997); Bannister (2002); Watkins and Schevill (1979)		Feeding	North Atlantic (Stellwagen Bank)	Depths <40 m		Several whales/ August/ Visual Observations	Hain et al. (1995)
Humpback whale					Feeding (possible)	Tropical Atlantic (Bermuda)	Dives to 240 m		One whale/ April/ VHF tag	Hamilton et al. (1997)
Humpback whale					Feeding (in breeding area)	Tropical Atlantic (Samana Bay - winter breeding area)	Not provided; lunge feeding with bubblenet		One whale/ January/ Visual observations	Baraff et al. (1991)

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Humpback whale					Breeding	North Pacific (Hawaii)	Depths in excess of 170 m recorded; some depths to bottom, others to mid- or surface waters; dive duration was not necessarily related to dive depth; whales resting in morning with peak in aerial displays at noon	40% in 0-10 m, 27% in 11-20 m, 12% in 21-30 m, 4% in 31-40 m, 3% in 41-50 m, 2% in 51-60 m, 2% in 61-70 m, 2% in 71-80 m, 2% in 81-90 m, 2% in 91-100 m, 3% in >100 m	Ten Males/ February-April/ Time-depth-recorder	Baird et al. (2000); Helweg and Herman (1994)
Humpback whale					Feeding	Northeast Atlantic (Greenland)	Dive data was catalogued for time spent in upper 8 m as well as maximum dive depth; diving did not extend to the bottom (~1000 m) with most time in upper 4 m of depth with few dives in excess of 400 m	37% of time in <4 m, 25% of time in 4-20 m, 7% of time in 21-35m, 4% of time in 36-50 m, 6% of time in 51-100 m, 7% of time in 101-150 m, 8% of time in 151-200 m, 6% of time in 201-300 m, and <1% in >300 m	Four whales/ June-July/ Satellite transmitters	Dietz et al. (2002)
Humpback whale					Feeding	North Pacific (Southeast Alaska)	Dives were short (<4 min) and shallow (<60 m); deepest dive to 148m; percent of time at surface increased with increased dive depth and with dives exceeding 60 m; dives related to position of prey patches		Several whales/ July-September/ Passive sonar	Dolphin (1987); Dolphin (1988)

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Gray whale	Amphipods, including *Ampelisca* sp, and other organisms living in the sea floor; also occasionally surface skim and engulfing; dependent on location; euphausiids along frontal systems may also be important	Continental shelf, 4-120 m depth	Dunham and Duffus (2002); Jones and Swartz (2002); Bannister (2002); Yazvenko et al. (2007); Bluhm et al. (2007)		Migrating	Northeast Pacific (coastal Baja California to northern California)	30 of 36 locations in depths <100m deep (mean 39 m); consistent speed indicating directed movement		One whale/ February/ Satellite tag	Mate and Urban Ramirez (2003)
Gray whale					Feeding	Bering and Chukchi Seas	Depths at feeding locations from 5-51 m depth		Several whales/ July-November/ Aerial surveys and benthic sampling	Clarke et al. (1989); Clarke and Moore (2002); Moore et al. (2003)
Gray whale					Feeding	Northeast Pacific (Kodiak Island)	Feeding on cumacean invertebrates		Several whales/ Year-round/ Aerial surveys	Moore et al. (2007)
Gray whale					Feeding	Northeast Pacific (Vancouver Island)	Majority of time was spent near the surface on interventilation dives (<3 m depth) and near the bottom (extremely near shore in a protected bay with mean dive depth of 18 m, range 14-22 m depth; little time spent in the water column between surface and bottom.	40% of time at <4 m (surface and interventilation dives), 38% of time at 3-18 m (active migration), 22% of time at >18 m (foraging).	One whale/ August/ Time-depth recorder	Malcolm et al. (1995/96); Malcolm and Duffus (2000)
ODONTOCETES - Toothed whales										

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Common Name	**Food Preference**	**Depth or Oceanic Preference**	**References**		**Behavioral State**	**Geographic Region**	**Depth Information**	**Depth Distribution**	**Sample Size/ Time of Year/Method**	**References**
Sperm whale	Squids and other cephalopods, demersal and mesopelagic fish; varies according to region	Deep waters, areas of upwelling	Whitehead (2002); Roberts (2003); Clarke (1986)		Feeding	Mediterranean Sea	Overall dive cycle duration mean = 54.78 min, with 9.14 min (17% of time) at the surface between dives; no measurement of depth of dive		16 whales/ July-August/ visual observations and click recordings	Drouot et al. (2004)
Sperm whale					Feeding	South Pacific (Kaikoura, New Zealand)	83% of time spent underwater; no change in abundance between summer and winter but prey likely changed between seasons		>100 whales/ Year-round/ visual observations	Jacquet et al. (2000)
Sperm whale					Feeding	Equatorial Pacific (Galapagos)	Fecal sampling indicated four species of cephalopods predominated diet, but is likely biased against very small and very large cephalopods; samples showed variation over time and place		Several whales/ January-June/ fecal sampling	Smith and Whitehead (2000)

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Sperm whale					Feeding	Equatorial Pacific (Galapagos)	Dives were not to ocean floor (2000-4000 m) but were to mean 382 m in one year and mean of 314 in another year; no diurnal patterns noted; general pattern was 10 min at surface followed by dive of 40 min; clicks (indicating feeding) started usually after descent to few hundred meters		Several whales/ January-June/ acoustic sampling	Papastavrou et al. (1989)
Sperm whale					Feeding	North Pacific (Baja California)	Deep dives (>100m) accounted for 26% of all dives; average depth 418 +- 216 m; most (91%) deep dives were to 100-500 m; deepest dives were 1250-1500m; average dive duration was 27 min; average surface time was 8.0; whale dives closely correlated with depth of squid (200-400 m) during day; nighttime squid were shallower but whales still dove to same depths	74% in <100 m; 24% in 100-500 m; 2% in >500m	Five whales/ October-November/ Satellite-linked dive recorder	Davis et al. (2007)

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Common Name	**Food Preference**	**Depth or Oceanic Preference**	**References**		**Behavioral State**	**Geographic Region**	**Depth Information**	**Depth Distribution**	**Sample Size/ Time of Year/Method**	**References**
Sperm whale					Resting/ socializing	North Pacific (Baja California)	Most dives (74%) shallow (8-100 m) and short duration; likely resting and/or socializing		Five whales/ October-November/ Satellite-linked dive recorder	Davis et al. (2007)
Sperm whale					Feeding	North Atlantic (Norway)	Maximum dive depths near sea floor and beyond scattering layer		Unknown # male whales/ July/ hydrophone array	Wahlberg (2002)
Sperm whale					Feeding	North Pacific (Southeast Alaska)	Maximum dive depth if 340 m when fishing activity was absent; max dive depth during fishing activity was 105 m		Two whales/ May/ acoustic monitoring	Tiemann et al. (2006)
Sperm whale					Feeding	Northwest Atlantic (Georges Bank)	Dives somewhat more U-shaped than observed elsewhere; animals made both shallow and deep dives; average of 27% of time at surface; deepest dive of 1186 m while deepest depths in area were 1500-3000 m so foraging was mid-water column; surface interval averaged 7.1 min		Nine Whales/ July 2003/ DTAG	Palka and Johnson (2007)

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Sperm whale					Feeding	Northwest Atlantic (Georges Bank)	37% of total time was spent near surface (0-10m); foraging dive statistics used to calculate percentages of time in depth categories, adjusted for total time at surface	48% in <10 m; 3% in 10-100 m; 7% in 101-300 m; 7% in 301-500 m; 4% in 501-636 m; 31% in >636 m	Six females or immatures/ September-October/ DTAG	Watwood et al. (2006)
Sperm whale					Feeding	Mediterranean Sea	20% of total time was spent near surface (0-10m); foraging dive statistics used to calculate percentages of time in depth categories, adjusted for total time at surface	35% in <10 m; 4% in 10-100 m; 9% in 101-300 m; 9% in 301-500 m; 5% in 501-623 m; 38% in >636 m	Eleven females or immatures/ July/ DTAG	Watwood et al. (2006)
Sperm whale					Feeding	Gulf of Mexico	28% of total time was spent near surface (0-10m); foraging dive statistics used to calculate percentages of time in depth categories, adjusted for total time at surface	41% in <10 m; 4% in 10-100 m; 8% in 101-300 m; 7% in 301-468 m; 40% >468 m	20 females or immatures/ June-September/ DTAG	Watwood et al. (2006)

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Common Name	**Food Preference**	**Depth or Oceanic Preference**	**References**		**Behavioral State**	**Geographic Region**	**Depth Information**	**Depth Distribution**	**Sample Size/ Time of Year/Method**	**References**
Sperm whale					Feeding/ Resting	North Pacific (Japan)	Dives to 400-1200 m; active bursts in velocity at bottom of dive suggesting search-and-pursue strategy for feeding; 14% of total time was spent at surface not feeding or diving at all, with 86% of time spent actively feeding; determined percentages of time in each depth category during feeding then adjusted by total time at surface	31% in <10 m (surface time); 8% in 10-200 m; 9% in 201-400 m; 9% in 401-600 m; 9% in 601-800m; 34% in >800 m	One female/ June/ Time-depth-recorder	Amano and Yoshioka (2003)

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Common Name	**Food Preference**	**Depth or Oceanic Preference**	**References**		**Behavioral State**	**Geographic Region**	**Depth Information**	**Depth Distribution**	**Sample Size/ Time of Year/Method**	**References**
Sperm whale					Feeding	North Pacific (Japan)	Diel differences in diving in one location offshore Japan, with deeper dives (mean 853 m) and faster swimming during the day than at night (mean 469 m); other location along Japan's coast showed no difference between day and night dives; most time (74%) spent on dives exceeding 200 m; surface periods of 2.9 h at least once per day; max depth recorded 1304 m		Ten whales/ May-June, October/ depth data loggers and VHF radio transmitters	Aoki et al. (2007)
Sperm whale					Feeding/ Resting	North Atlantic (Caribbean)	Whales within 5 km of shore during day but moved offshore at night; calves remained mostly at surface with one or more adults; night time tracking more difficult due to increased biological noise from scattering layer; both whales spent long periods of time (>2hr) at surface during diving periods		Two whales/ October/ Acoustic transponder	Watkins et al. (1993)

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Sperm whale						North Atlantic (Caribbean)	Dives did not approach bottom of ocean (usually >200 m shallower than bottom depth); day dives deeper than night dives but not significantly; 63% of total time in deep dives with 37% of time near surface or shallow dives (within 100 m of surface)		One whale/ April/ Time-depth tag	Watkins et al. (2002)
Sperm whale					Feeding	Northern Pacific (Hawaii)	Cephalopods of several genera recovered		Two animals/ unknown/ stomach contents	Clarke and Young (1998)
Sperm whale					Occurrence	Mediterranean Sea (Alborian Sea south of Spain)	Preferred waters >700m		Vessel transects	Canadas et al. (2002)

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Sperm whale					Feeding	Arctic Ocean (Norway)	Dives from 14-1860 m with median of 175 m; clicking (searching for prey) began at 14-218 m and stopped at 1-1114 m, and whale spent 91% of overall dives emitting clicks; shallower dives were apparently to target more sparse prey while deep dives led to frequent prey capture attempts and were likely within denser food layers		Four adult males/ July/ DTAG	Teloni et al. (2007)
Pygmy sperm whale	Mid and deep water cephalopods, fish, crustaceans; probably feeding at or near bottom, possibly using suction feeding	Continental slope and deep zones of shelf, epi- and meso-pelagic zones	McAlpine (2002); McAlpine et al. (1997); Clarke (1986)		Feeding	Northwest Atlantic (Canada)	Prey items included squid beaks, fish otolith and crustacean; squids representative of mesopelagic slope-water community		One whale/ December/ Stomach contents	McAlpine et al. (1997)
Pygmy sperm whale					Feeding	Southwest Atlantic (Brazil)	Small to medium-sized cephalopods from offshore regions; cephalopods and fish found in animals from shelf regions		unknown animals/ unknown/ stomach contents	Santos and Haimovici (2001)

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Pygmy sperm whale					Feeding	South Pacific (New Zealand)	Primarily cephalopod prey of genus *Histioteuthis* sp, mostly immatures, which is know to undergo vertical migrations; also mysids that are usually found at 650 m during day and between 274 and 650 m at night; some prey species also found in shallower (<100 m) depths in trawls		27 whales/ Year round/ Stomach contents	Beatson (2007)
Dwarf sperm whale	Likely feeds in shallower water than *K breviceps*; otherwise food is similar	Continental slope and deep zones of shelf, epi- and meso-pelagic zones	McAlpine (2002); Clarke (1986)							

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Blainville's beaked whale	Feed primarily on mesopelagic squid (*Histioteuthis, Gonatus*) and some mesopelagic fish; most prey probably caught at >200 m; likely suction feeders based on lack of teeth and enlarged hyoid bone and tongue muscles		Pitman (2002); Clarke (1986)		Feeding	Northeast Pacific (Hawaii)	Max dive depth = 1408 m; identified at least three dive categories including inter-ventilation (<5 m), long duration (>800m, U-shaped but with inflections in bottom depth), and intermediate duration (6-300 m, U-shaped); dive cycle usually included one long duration,~8 intermediate duration and several shallow interventilation dives; one surface interval of >154 min; no difference between day and night diving		Four whales/ September-November/ Time-depth recorders	Baird et al. (2006a); Baird et al. (2005a)
Blainville's beaked whale					Feeding	Northeast Pacific (Hawaii)	Mean max dive depth = 1365 m; whales appeared to coordinate dives to ~600 m after which coordination of depths was not prevalent; dives >800 m (>65 min) occurred once/2.5 hour; likely feeding in mid-depth, not bottom feeding		Three whales/ March-April/ Time-depth recorders	Baird et al. (2006c)

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Blainville's beaked whale					Feeding	Northeast Atlantic (Canary Islands)	Two types of dive, U-shaped deep foraging dives (>500 m, mean 835m) and shallower non-foraging dives (<500 m, mean 71 m)	26% in <2 m (surface); 41% in 2-71 m; 2% in 72-200 m; 4% in 201-400 m; 4% in 401-600 m; 4% in 601-835; 19% in >835 m	Three whales/ June/ DTAGs	Tyack et al. (2006)
Blainville's beaked whale					Feeding	Northeast Atlantic (Canary Islands)	Deep dives broken into three phases: silent descent, vocal-foraging (including search, approach and terminal phases) and silent ascent; vocalizations not detected <200m depth; detected when whales were as deep as 1267 m; vocalizations ceased when whale started ascending from dive; clicks ultrasonic with no significant energy below 20 kHz		Two whales/ September/ DTAGs	Johnson et al. (2004); Madsen et al. (2005)

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Baird's beaked whale	Benthic fishes and cephalopods, also pelagic fish including mackerel and sardine; primarily squid off northern coast of Hokkaido and deep sea fish off Pacific coast of Japan	Deep waters over continental slope	Kasuya (2002); Kasuya (1986); Walker et al. (2002); Clarke (1986)		Feeding	Northwest Atlantic (Japan)	Whales caught at depths of ~1000 m; stomach contents included prey species normally found from 1100-1300 m; likely feeding at or near bottom		Several whales/ August-September/ Stomach contents	Ohizumi et al. (2003)
Northern bottlenose whale	Squid of genus *Gonatus* and *Taonius* and occasionally fish and benthic invertebrates	Deep waters >500 m; can dive to >1400 m	Gowans (2002); Kasuya (2002); Clarke and Kristensen (1980); Clarke (1986)		Feeding	Northeast Atlantic (Nova Scotia "Gully")	Most (62-70%, average = 66%) of the time was spent diving (deeper than 40 m); most dives somewhat V-shaped; shallow dives (<400 m) and deep dives (>800 m); whales spent 24-30% (therefore, average of 27%) of dives at 85% maximum depth indicating they feed near the bottom; deepest dive 1453 m	34% at 0-40 m, 39% at 41-800 m, 27% at >800 m	Two whales/ June-August/ Time-depth recorders	Hooker and Baird (1999)

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Killer whale	Diet includes fish (salmon, herring, cod, tuna) and cephalopods, as well as other marine mammals (pinnipeds, dolphins, mustelids, whales) and sea birds; most populations show marked dietary specialization	Widely distributed but more commonly seen in coastal temperate waters of high productivity	Ford (2002); Estes et al. (1998); Ford et al. (1998); Saulitis et al. (2000); Baird et al. (2006b)		Feeding	North Pacific (Puget Sound)	Resident-type (fish-eater) whales; maximum dive depth recorded 264 m with maximum depth in study area of 330 m; population appeared to use primarily near-surface waters most likely because prey was available there; some difference between day and night patterns and between males and females depth distribution info from Table 5 in Baird et al. (2003)	96% at 0-30 m; 4% at >30 m	Eight whales/ Summer-fall/ Time-depth recorders	Baird et al. (2005b); Baird et al. (2003)
Killer whale					Feeding	Southwest Atlantic (Brazil)	Small to medium-sized cephalopods, both offshore and coastal		Unknown animals/ unknown/ stomach contents	Santos and Haimovici (2001)
Risso's dolphin	Primarily squid eaters and presumably eat mainly at night; known to feed on oceanic species that are also bioluminescent	Water depths from 400-1000 m but also on continental shelf; utilize steep sections of continental slope in GOM (350-975 m)	Baird (2002b); Baumgartner (1997); Bello (1992); Clarke (1986)		Feeding	Mediterranean (western)	Prey items were mainly squids and octopods, and indicated that most feeding occurs on the middle slope from 600-800 m		15 animals/ year round/ stomach contents	Blanco et al. (2006)
Risso's dolphin					Feeding	Mediterranean (Turkey)	Prey species (pelagic cephalopods) show greater degree of vertical		Two animals/ May-June/ stomach contents	Ozturk et al. (2007)

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							distribution compared to those utilized by *S. coeruleoalba*; may indicate they dive deeper or are more likely to feed at night			
Risso's dolphin					Feeding	Mediterranean (Ligurian Sea)	Diet composed of cephalopods found at daytime depths in excess of 300 m and which may undertake vertical migrations at night		One animal/ August/ stomach contents	Wurtz et al. (1992)
Risso's dolphin					Feeding	Northern Pacific (Hawaii)	Cephalopods of several genera recovered		One animal/ unknown/ stomach contents	Clarke and Young (1998)
Risso's dolphin					Feeding	North Atlantic (England)	Squid, octopod and cuttlefish were present, all live on the continental shelf		One animal/ May/ stomach contents	Clarke and Pascoe (1985)
Risso's dolphin					Occurrence	Mediterranean Sea (Alborian Sea south of Spain)	Found in waters >600 m with no sightings <400 m		Vessel transects	Canadas et al. (2002)
Striped dolphin					Feeding	Mediterranean (western)	Mixed diet of muscular and gelatinous body squids, mainly consisting of oceanic and pelagic or bathypelagic species		28 animals/ unknown/ stomach contents	Blanco et al. (1995)

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Striped dolphin					Feeding	North Pacific (Japan)	Myctophid fish accounted for 63% of prey		Unknown animals/ unknown/ stomach contents	Archer and Perrin (1999)
Striped dolphin					Feeding	Mediterranean (Ligurian Sea)	Diet composed of cephalopods, crustaceans and bony fishes; cephalopods and bony fishes apparently equal in importance; likely feeding in offshore waters and possibly in the upper water column; opportunistic feeders		23 animals/ unknown/ stomach contents	Wurtz and Marrale (1993)
Striped dolphin					Feeding	Mediterranean Sea (Ionian Sea)	Prey items included cephalopods, fish and shrimp; feeding likely was benthopelagic although feeding may have taken advantage of species undergoing night time vertical migrations as well		One animal/ May/ stomach contents	Bello (1992)
Striped dolphin					Feeding	North Atlantic (Ireland)	Remains included Gadidae, Clupeidae and cephalopods		Seven animals/ year round/ stomach contents	Berrow and Rogan (1996)
Striped dolphin					Occurrence	Mediterranean Sea (Alborian Sea south of Spain)	Found rarely on continental shelf waters and rather in waters >600 m		Vessel transects	Canadas et al. (2002)

GENERAL INFORMATION					DEPTH SPECIFIC INFORMATION					
Common Name	**Food Preference**	**Depth or Oceanic Preference**	**References**		**Behavioral State**	**Geographic Region**	**Depth Information**	**Depth Distribution**	**Sample Size/ Time of Year/Method**	**References**
Striped dolphin	Feed on pelagic fish and squid; squid make up 50-100% of stomach contents in Mediterranean samples	Continental slope, convergence zones and areas of upwelling; ranges of known prey and presence of luminescent organs in prey indicate feeding at night, possibly 200-700 m	Archer (2002); Archer and Perrin (1999); Clarke (1986)		Feeding	Mediterranean (Turkey)	Prey species (pelagic cephalopods) show lesser degree of vertical distribution compared to those utilized by *G. griseus*		Three animals/ May-June/ stomach contents	Ozturk et al. (2007)
Pantropical spotted dolphin	Small epipelagic fishes, squids and crustaceans for offshore forms; near shore forms may feed on benthic fishes; perhaps some nocturnal feeding; probably opportunistic	Near shore and offshore, with possible shifts closer to shore in fall and winter; in eastern tropical Pacific often found in association with tuna; diet suggest feeding at night on vertically migrating prey	Perrin (2002a); Richard and Barbeau (1994); Robertson and Chivers (1987); Clarke (1986)		Feeding	Southwest Pacific (Taiwan)	Feed primarily on mesopelagic prey, particularly myctophid lanternfish and cephalopods, with some seasonal differences; night distribution of prey appears to be 0-200 m while daytime distribution of prey is >300 m		45 animals/ year round/ stomach contents	Wang et al. (2003)
Pantropical spotted dolphin					Feeding	North Pacific (Hawaii)	Dives deeper at night (mean = 57 m, max = 213 m) than during day (mean = 13 m, max = 122 m) indicating night diving takes advantage of vertically migrating prey; during daytime, 89% of time was within 0-10 m	For activities conducted during daytime-only, the depth distribution would be 89% at 0-10 m, 10% at 11-50 m, 1% at 51-122 m; for activities conducted over a 24-hour period, the depth distribution needs to be modified to	Six animals/ year round/ time-depth recorders	Baird et al. (2001)

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								reflect less time at surface and deeper depth dives; 80% at 0-10 m, 8% at 11-20 m, 2% at 21-30 m, 2% at 31-40 m, 2% at 41-50 m, and 6% at 51-213 m.		
Pantropical spotted dolphin					Feeding	Northern Pacific (Hawaii)	Remains of cephalopods and fish recovered		One animal/ unknown/ stomach contents	Clarke and Young (1998)
Pantropical spotted dolphin					Feeding/ travelling	Eastern Tropical Pacific	Daytime dives to 5-20 m (above thermocline) and U-shaped (travelling dives); nighttime dives were deeper and below thermocline, characterized by rapid up and down movements at depth (foraging dives); deepest dive to 200 m though most were not that deep		Nine animals/ August-October/ time-depth recorders	Chivers and Scott (2002)
Pacific white-sided dolphin	Lanternfish, anchovies, hake and squid; also herring, salmon, cod, shrimp and capelin	Mostly pelagic and temperate; may synchronize movements with anchovy and other prey	van Waerebeek and Wursig (2002); Clarke (1986)		Feeding	Northeast Pacific (British Columbia inland waters)	Prey collected included herring, capelin, Pacific sardine and possibly eulachon		Unknown/ year round/ dipnet collection of prey	Morton (2000)
Atlantic white-sided dolphin	Herring, small mackerel, gadid fishes, smelts, hake, sand lances, squid;	Continental shelf and slope from deep oceanic areas to occasionally	Cipriano (2002); Clarke (1986)			North Atlantic (Gulf of Maine)	Most (89%) of time spent submerged; most (76%) dives were <1		One animal/ February/ satellite-monitored radio	Mate et al. (1994)

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Common Name	**Food Preference**	**Depth or Oceanic Preference**	**References**		**Behavioral State**	**Geographic Region**	**Depth Information**	**Depth Distribution**	**Sample Size/ Time of Year/Method**	**References**
	likely change from season to season	coastal waters					min duration and none were for longer that 4 minute duration		tag	
Atlantic white-sided dolphin					Feeding	North Atlantic (Ireland)	Most frequent prey were mackerel and silvery pout		Four animals/ year round/ stomach contents	Berrow and Rogan (1996)
White-beaked dolphin	Mesopelagic fish, especially cod, whiting and other gadids, and squid		Kinze (2002); Clarke (1986)		Feeding	North Atlantic (Ireland)	Stomach contained Gadoid fish and scad remains		One animal/ year round/ stomach contents	Berrow and Rogan (1996)
Short-beaked common dolphin	Small mesopelagic fishes and squids in the deep scattering layer; epipelagic schooling fishes and market squids	Wide range of habitats, including upwelling areas, oceanic and near shore regions	Perrin (2002b); Clarke (1986)		Feeding	Southwest Atlantic (Brazil)	Cephalopods and fish found in animals from shelf regions		Two animals/ unknown/ stomach contents	Santos and Haimovici (2001)
Short-beaked common dolphin					Feeding	Northeast Atlantic (Bay of Biscay)	Oceanic diet dominated by myctophid fishes (90%), with less reliance on cephalopods; appear to forage preferentially on small schooling, vertically migrating mesopelagic fauna at dusk and early evening		63 animals/ June-August/ stomach contents	Pusineri et al. (2007)
Short-beaked common dolphin					Feeding	Unknown	Dives to 200 m, apparently from study reported by Evans (1994)		Unknown/ unknown/ unknown	Perrin (2002b)

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Short-beaked common dolphin					Feeding	Western North Pacific	Primarily myctophid fishes and other warm water fish species; most prey species found are those that migrate vertically to shallower depth at night (within few hundred m) or inhabit upper layer of ocean		Ten animals/ September/ stomach contents	Ohizumi et al. (1998)
Short-beaked common dolphin					Feeding	Mediterranean Sea	Diet of shoaling fish and eurybathic cephalopods and crustceans			Bearzi et al. (2003)
Short-beaked common dolphin					Feeding	Mediterranean Sea (Algeria)	Diet composed of pelagic fishes (94%) and cephalopods (6%); most prey of low commercial value		Ten animals/ unknown/ stomach contents	Boutiba and Abdelghani (1996)
Short-beaked common dolphin					Feeding	North Pacific	Fish accounted for 94% of the diet (mostly myctophid fish), with squids making up 6% of diet		Seven animals/ May-November/ stomach contents	Chou et al. (1995)
Short-beaked common dolphin					Feeding	North Atlantic (mid-Atlantic Bight offshore New Jersey)	Atlantic mackerel and long-finned squid		Four animals/ March-April/ stomach contents	Overholtz and Waring (1991)
Short-beaked common dolphin					Feeding	Mediterranean Sea (Ligurian Sea)	Prey consisted of offshore species of fish, decapod crustaceans and cephalopods; similar diet to that found in		Three animals/ unknown/ stomach contents	Relini and Relini (1993)

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							striped dolphins			
Short-beaked common dolphin					Feeding	North Atlantic (Portuguese coast)	Prey remains mostly fish (90%), especially blue whiting and sardine, followed by cephalopods (10%)		26 animals/ year round/ stomach contents	Silva and Sequeira (1997)
Short-beaked common dolphin					Feeding	Indian Ocean (South Africa)	Feeding associated with northward sardine migration; most prey were pelagic shoaling species, mostly South African pilchard, and squid		297 animals/ year round/ stomach contents	Young and Cockcroft (1994)
Short-beaked common dolphin					Feeding	North Atlantic (Ireland)	Remains included Gadidae, Clupeidae and cephalopods		27 animals/ year round/ stomach contents	Berrow and Rogan (1996)
Long-beaked common dolphin	Small mesopelagic fishes and squids in the deep scattering layer; epipelagic schooling fishes and market squids	Somewhat shallower and warmer water than short-beaked; closer to the coast	Perrin (2002b)		Feeding	Unknown	Unknown	Dives to 200 m, apparently from study reported by Evans (1994)	Unknown	Perrin (2002b)
Northern right whale dolphin	Squid and lanternfish, also Pacific hake, saury and mesopelagic fish		Lipsky (2002); Clarke (1986)		Feeding	North Pacific	Fish accounted for 89% of the diet (mostly myctophid fish), with squids making up 11% of diet		Seven animals/ May-November/ stomach contents	Chou et al. (1995)

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Spinner dolphin	Small mesopelagic fishes, although subpopulations consume benthic fishes; also cephalopods	Pantropical; often high-seas, but coastal populations are also known; dives to 600 m or deeper	Perrin (2002c); Benoit-Bird and Au (2003); Clarke (1986)		Feeding	Southwest Pacific (Sulu Sea, Philippines)	Mainly feed on mesopelagic crustaceans, cephalopods and fish that undertake vertical migrations to about 200 m at night, with less reliance on non-migrating species found to about 400 m; take smaller prey than Fraser's feeding in same area		45 animals/ unknown/ stomach contents	Dolar et al. (2003)
Spinner dolphin					Feeding	North Pacific (Hawaii)	Extremely close association with small, mesopelagic fishes; mean depth always within 10 m of the depth of the highest prey density; feeding at night occurs between 0-400 m as that is the nighttime prey distribution (prey distribution during the day is estimated at 400-700 m); did not spend entire night offshore but often within 1 km of shore if prey density was highest there	100% at 0-50 m; nighttime: 100% at 0-400 m.	Several animals/ June and November/ active acoustic surveys	Benoit-Bird and Au (2003)

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Dall's porpoise	Small schooling and mesopelagic fish and cephalopods	Deep offshore as well as deeper near shore waters; diurnal as well as nocturnal feeders to take advantage of prey availability	Jefferson (2002), Amano et al. (1998); Clarke (1986)		Travelling	North Pacific (Puget Sound)	Feasibility study to determine if Dall's could be successfully tagged with suction cup tag; depth distribution info excludes initial dive data when animal responded to tag event	39% at <1 m, 8% at 1-10 m, 45% at 11-40 m and 8% at >40 m	One animal/ August/ time-depth recorder	Hanson and Baird (1998)
Harbor porpoise	Fish and squid eaters; fish with high fat content including herring, sprat, and anchovy	Forage near bottom in waters less than 200 m; can dive to >220 m	Bjorge and Tolley (2002); Clarke (1986)		Feeding	North Atlantic (Ireland)	Most frequent prey were *Trisopterus*, whiting, *Merlangius* and sprat; mostly pelagic species		26 animals/ year round/ stomach contents	Berrow and Rogan (1996)
Harbor porpoise					Feeding/ migrating	Northwest Pacific (Japan)	>90% of dives were <10 m; maximum dive depth of 65 m with mean of 3.8 m		One animal/ July/ micro data logger	Otani et al. (2000)
Harbor porpoise					Feeding/ migrating	Northwest Pacific (Japan)	Diving occurred almost continuously with little long-term surface time; maximum depths of 99 and 71 m, with >70% of diving time at <21 m; shallow dives (<21 m) V-shaped with little bottom time; deeper dives (>90 m) U-shaped with noticeable bottom time	75% at 0-20 m, 15% at 21-40 m, and 10% at >40 m.	Two females/ April-May/ micro-dataloggers	Otani et al. (1998)

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Harbor porpoise					Feeding	Northeast Atlantic	Shift from predation on clupeid fish (herring and sprat) to sand eels and gadoid fish (whiting) following decline in herring stocks		Literature review of stomach content papers	Santos and Pierce (2003)
Harbor porpoise					Feeding	Northwest Atlantic (Bay of Fundy)	Maximum recorded depth was 226 m, with mean dive depths of 14 to 41 m; long, deep dives infrequent; most dives were U-shaped with bottom time accounting for 27-39% of total dive time (bottom time does not equal ocean bottom); 33-60% of time spent within top 2 m of surface		Seven animals/ August-September, time-depth recorders	Westgate et al. (1995)
Harbor porpoise						Northwest Atlantic (Bay of Fundy, Gulf of Maine)	Most of time (55%) was spent in water depth ranging from 92-183 m, with only 12% of time spent in water >183 m deep; 3-7% of total time was spent at the surface		Nine animals/ August/ satellite-linked transmitters	Read and Westgate (1997)
CARNIVORES - Pinnipeds and sea otters										

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Northern fur seal	Small fish and squid in deep water and along the shelf break; Pacific herring, squid and walleye pollock dominated in the Gulf of Alaska, British Columbia, Washington and Oregon; northern anchovy and squid primary in Oregon, Washington and California	Deep dives occur on the shelf and feeding probably occurs near the bottom	Gentry (2002); Ream et al. (2005)				Maximum dive depth 256 m		Two females/ July/ time-depth recorders	Ponganis et al. (1992)
Northern fur seal					Feeding	North Pacific (Bering Sea)	Mean dive depth 68 m (range 32-150 m); mean maximum depth 168 m (range 86-207 m); two types of dives, shallow (<75 m; mean = 30 m; occur at night) and deep (>75 m; mean = 130 m; occur during day and night); total activity budget during feeding trips was 57% active at surface, 26% diving and 17% resting; depth distribution info from Gentry and others	Daytime: 74% at <2 m, 24% at 2-260 m; night time: 74% at <2 m, 24% at 2-75 m	Seven females/ July/ time-depth recorders	Gentry et al. (1986)
Northern fur seal					Feeding	North Pacific (Bering Sea)	Mean dive depth of 17.5 m, with a maximum depth of 175 m; diving deeper in the daytime than during nighttime,		19 juvenile males/ July-September/ satellite transmitters	Sterling and Ream (2004)

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							perhaps reflecting the different distribution of prey (especially juvenile pollock) that undertake night time vertical migrations, and also differed between inner-shelf, mid-shelf, outer-shelf and off-shelf locations; deeper diving tended to occur on-shelf, with shallower diving off-shelf			
Northern fur seal					Feeding	North Pacific (Bering Sea to California)	Higher dive rates during night time hours compared with daytime; variation in mean dive depth between migratory travelling and destination area (eastern North Pacific coast) where mean dive depth was <25 m; night time mean dive depths were greater during full moon than during new moon		Three females/ November-May/ satellite transmitters	Ream et al. (2005)
Northern fur seal					Feeding	North Pacific (Bering Sea)	Activity budgets of lactating females of 44% locomoting, 23% diving and 33% resting at the surface		Four females/ August/ platform terminal transmitters	Insley et al. (2008)

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Northern fur seal					Migrating	North Pacific (Bering Sea to Gulf of Alaska)	Diving behavior consistent regardless of habitat (pelagic or continental shelf); diving largely at night and in evening and morning with little diving during day suggesting feeding on vertically migrating prey	71% at <2 m, 14% at 2-5 m, 5% at 6-10 m, 6% at 11-25 m and 3% at 26-50 m	20 post-weaning pups/ November-May/ satellite-linked time-depth recorders	Baker (2007)
Steller sea lion	Fish, including walleye pollock, Pacific herring, sand lance, salmon, flounder, rockfish and cephalopods	Diets and feeding patterns change with seasons; population levels are related to prey with increasing populations correlated with diverse diets and decreasing populations correlated with diets of primarily one prey item; females feed mostly at night during breeding season; feeding occurs throughout the day during non-breeding season	Trites et al. (2007); Loughlin (2002); Merrick et al. (1994)		Feeding	North Pacific (southeast Alaska)	Characterized by relatively brief trips to sea that represent about on-half of total time, and by fairly frequent, short and shallow dives that occur mostly at night. Maximum depth recorded was 424 m; mean depth was 26.4 m, and 49% of all dives were <10 m.		13 females/ May-June, January/ satellite-linked time-depth recorders	Swain (1996)
Steller sea lion					Feeding	North Pacific (Gulf of Alaska)	Adult females forage close to land in summer (<20 km) and make brief trips (<2 days) and shallow dives (<30 m); in winter, divers are		Two females/ unknown/ satellite-linked time-depth recorder	Merrick et al. (1994)

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							longer in distance (up to 300 km), time (up to several months) and deeper (>250 m), Average dive depth of 36.5 and 42.9 m			
Steller sea lion						North Pacific (Gulf of Alaska)	Adult females capable of foraging throughout GOA and Bering Sea, while young-of-year have smaller ranges and shallower dives; females in winter dove deepest (median 24 m, maximum >250 m, while young-of-year were shallowest (median 9 m, max 72 m); depth distribution represents averaging of all age/season classes	60% at 0-10 m, 22% at 11-20 m, 12% at 21-50 m, 5% at 51-100 m and 1% at >100 m.	15 animals/ June-July, November-March/ satellite-linked time-depth recorders and VHF transmitters	Merrick and Loughlin (1997)
Steller sea lion						North Pacific (Gulf of Alaska)	Young of year dove for shorter periods and shallower depths than yearlings; maximum dive depth was 288 m; long-range transits began at >10 months of age	78% in 0-10 m, 13% in 11-20 m, 7% in 21-50 m, and 2% in > 51 m	18 animals/ October-June/ satellite-linked time-depth recorders	Loughlin et al. (2003)

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Steller sea lion						North Pacific (Washington)	Maximum dive depth was 328 m	28% in 0-10 m, 30% in 11-20 m, 18% in 21-50 m, 14% in 51-100 m and 10% in >100 m	Seven animals/ October-June/ satellite-linked time-depth recorders	Loughlin et al. (2003)
Steller sea lion						North Pacific (Gulf of Alaska)	Juveniles from western Alaska rookeries left on foraging trips at dusk and returned at dawn (taking advantage of pollock that vertically migrates and hauling out during the day), while juveniles from eastern Alaska rookeries left on foraging trips throughout the day and night, likely feeding on prey other than vertical migrants		129 animals/ August-November, January-May/ satellite dive recorders	Call et al. 2007)
Steller sea lion						North Pacific (Gulf of Alaska)	Round trip distance and duration of pups and juveniles increased with age, trip distance was greater for western rookeries than for eastern rookeries, trip duration was greater for females than males; 90% of trips were <=15		103 animals/ year round/ satellite dive recorders	Raum-Suryan et al. (2004)

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							km from haul-outs; dispersals >500 km were undertaken only by males although dispersals of >120 km were common			
California sea lion	Feed on a wide assortment of fish, including anchovy, whiting, rockfish and mackerel, as well as cephalopods; diet depends on season, location and oceanographic conditions		Heath (2002); Costa et al. (2007)		Feeding	North Pacific (Channel Islands)	Generally shallow water divers but showed extensive variation in behavior among females; spent 67% of total time at sea (33% at rookery); with average dive depth of 58.2 m		25 females/ October-January/ time-depth recorders	Costa et al. (2007)
California sea lion					Feeding	North Pacific (Monterey Bay)	Larger males dived longer and spent less time at sea and more time hauled out; maximum dive depth of 575 m although mean dive depth was 32.2 m and 86% of dives were <50 m; 50% of total time at haulouts; 32% of time at surface and remainder of time was diving		25 males/ October-January/ satellite-relay data loggers	Costa et al. (2007)

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California sea lion					Feeding	North Pacific (Channel Islands)	Deepest dive estimated at 274 m but most dives were <80 m; less than 5% of all dives were >200 m; peak diving frequency near sunrise and sunset, but diving was recorded during all hours; activity patterns showed that ~33% spent diving, ~41% spent swimming between dives, ~23% at the surface during dive bouts, and 3% spent resting; seasonal and diel diving patterns suggested that prey presence strongly influences depth and duration of dives; depth distribution inferenced from text and various figures	26% at <2 m (surface), 41% at 2-10 m (swimming between dive bouts), 3% at 11-19 m, 17% at 20-60 m and 13% at >60 m.	10 females/ Jul-August/ Time-depth recorders	Feldkamp et al. (1989)
Northern elephant seal	Feed on deep-water squid and fish, and likely spend about 80% of their annual cycle at sea feeding; feed in meso-pelagic zone on vertically migrating squid	Deeper waters (>1000 m); males farther north than females	Hindell (2002); Stewart and DeLong (1993; 1995); LeBoeuf et al. (1988); Asaga et al. (1994); LeBoeuf (1994)		Feeding	North Pacific	Dive continuously for 8-10 months/year; dispersion and migratory patterns related to oceanographic features and areas of biological productivity;		36 adults (both sexes)/ February-August/ dive and location recorders	Stewart and Delong (1993)

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							primarily squid eaters; males travel farther than females; females submerged 91% and males submerged 88% of time at sea; dive continuously; average depth for females was 479 m (post-molt) and 518 m (post-breeding) and for males 364 m (post-breeding) and 366 m (post-molt)			
Northern elephant seal					Feeding	North Pacific	seals use same foraging areas during post-breeding and post-molting periods; sexes are segregated geographically		36 adults (both sexes)/ January-February; May; July/ geographic location time depth recorders	Stewart and DeLong (1995)
Northern elephant seal					Feeding	North Pacific	little time at depths <200 m or >800 m; post-breeding migration is directed northward and quick until feeding areas are obtained; dives in transit are shallower than those on foraging grounds		14 adults (both sexes)/ February-July/ geographic location time depth recorders	Stewart and DeLong (1994)

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Northern elephant seal					Feeding	North Pacific	Sea surface temperature appears to influence female forage area choice; foraging occurred in near shore areas of Gulf of Alaska, offshore Gulf of Alaska, near shore off Washington and Oregon and offshore between 40 and 50 N		12 adult females/ year round/ time depth recorders	Simmons et al. (2007)
Northern elephant seal					Feeding	North Pacific	Post-lactation monitoring; 86% of time at-sea spent submerged; maximum dive of 894 m, but dives >700 m were rare; modal dive depths between 350 and 650 m; continuous deep diving while at-sea; night dives were more numerous, shallower and of shorter duration; most dives types D (deep and u-shaped)		Seven adult females/ February-March/ time-depth recorders	LeBoeuf et al. (1988)
Northern elephant seal					Feeding	North Pacific	Mean depth of dive 333 m; maximum dive 630 m; 6% of all dives <200 m		One adult female/ February/ time-depth recorder	LeBoeuf et al. (1986)

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Northern elephant seal					Feeding	North Pacific	Differences in foraging locations and behavior between males and females; females exhibited pelagic diving with varying dive depths depending on prey location in deep scattering layer; males exhibited pelagic diving as well as flat-bottom benthic dives near continental margins; males migrated to northern Gulf of Alaska and eastern Aleutians with females distributed west to 150 W between 44 and 52 N		32 adults (both sexes)/ March-July/ radio-telemetry	LeBoeuf et al. (1993)
Northern elephant seal					Transiting	North Pacific	90% of time submerged; mean depth 289 m; directed swimming even while submerged used prolonged gliding during dive descents which reduces cost of transport and can increase the duration of the dive		One adult female/ April/ video and satellite telemetry	Davis et al. (2001)

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Northern elephant seal					Feeding	North Pacific	Type D (foraging) dives account for 75-80% of all dives; type A (transit dives) rarely occurred in series; type C dives were shallowest; type D dives which are foraging dives as they are the most common	9% at <2 m, 11% at 2-100 m, 11% at 101-200 m, 11% at 201-300 m, 11% at 301-400 m, 11% at 401-500 m and 36% at >500 m.	Two adult females/ February-May/ time-depth recorders	Asaga et al. (1994)
Northern elephant seal					Feeding	North Pacific	Transit dives in males cover large horizontal distances and are shallower than pelagic dive depths; transit dives in females and juveniles are both for transiting and search for prey patches; foraging dives have steeper angles than transit dives in females, but angles are not noticeably different in juveniles; swim speeds were similar across age and sex		16 animals (various ages)/ April-May/ time-depth recorders and platform terminal transmitters	Hassrick et al. (2007)

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Common Name	**Food Preference**	**Depth or Oceanic Preference**	**References**		**Behavioral State**	**Geographic Region**	**Depth Information**	**Depth Distribution**	**Sample Size/ Time of Year/Method**	**References**
Northern elephant seal					Feeding	North Pacific	Males feed primarily from coastal Oregon to western Aleutian Islands, along continental margin and feed primarily on benthic organisms, migration is direct to forage areas across Pacific; females have wider foraging area from 38-60 N and from the coast to 172 E, and forage on pelagic prey in the water column, migration is more variable to take advantage of prey patches		47 adults (both sexes)/ March-June, September-December/ time-depth swim speed recorders	LeBoeuf et al. (2000)
Northern elephant seal					Feeding, Transiting	North Pacific	Different types of dives serve three general functions: type AB dives are transit dives (covering great horizontal distance and with shallow ascent and descent angles); type C dives are "processing" dives for internal processes such as digestions (slower swimming speed and short horizontal		unknown	Crocker et al. (1994)

GENERAL INFORMATION					DEPTH SPECIFIC INFORMATION					
Common Name	**Food Preference**	**Depth or Oceanic Preference**	**References**		**Behavioral State**	**Geographic Region**	**Depth Information**	**Depth Distribution**	**Sample Size/ Time of Year/Method**	**References**
							distance; type DE dives are foraging (both chasing prey pelagically and benthic foraging)			
Harbor seal	Feed on fish, octopus, squid, shrimp and other available prey; Pacific herring and salmon in Washington inland waters; may spend ~85% of the day diving for food		Reeves et al. (2002); Suryan and Harvey (1998); Baechler et al. (2002)		Feeding/ travelling	North Atlantic (Sable Island)	Two primary types of dives, U-shaped and V-shaped, with strong relationship between U-shaped and foraging; dive shapes differ between age and sex classes and behavioral state (e.g., pre-mating versus lactating)		Several/ May-June/ time-depth recorders	Baechler et al. (2002)

GENERAL INFORMATION					DEPTH SPECIFIC INFORMATION					
Common Name	**Food Preference**	**Depth or Oceanic Preference**	**References**		**Behavioral State**	**Geographic Region**	**Depth Information**	**Depth Distribution**	**Sample Size/ Time of Year/Method**	**References**
Harbor seal					Feeding	North Atlantic (Sable Island)	Lactating females spent 45% of time on land with their pups, 55% of time at sea and only 9% of the total time actively diving; pups often accompanied females but did not dive as long; maximum dive depth 59 m; mean dive depth 9-11 m		Twenty females/ May-June/ time-depth recorders	Bowen et al. (1999)
Harbor seal					Feeding	North Pacific (Monterey Bay)	80% of dives classified as square (U-shaped) and associated with feeding; 11% were V-shaped dives associated with travelling; deepest dive 481 m; most dives to 5-100 m; foraging mostly at mid-depth (median 52 m for males and 40 m for females); depth distribution inferred from text	50% at <3 m, 20% at 3-50 m, 25% at 51-100 m and 5% at >100 m.	Twenty animals/ year round/ time-depth recorders	Eguchi and Harvey (2005)

GENERAL INFORMATION				DEPTH SPECIFIC INFORMATION					
Common Name	**Food Preference**	**Depth or Oceanic Preference**	**References**	**Behavioral State**	**Geographic Region**	**Depth Information**	**Depth Distribution**	**Sample Size/ Time of Year/Method**	**References**
Harbor seal				Feeding	North Atlantic (Svalbard)	50% of diving was <40 m and 95% of diving was <250 m; maximum dive depth of 452 m, most maximum dive depths were 100-200 m and may have been to sea floor or intermediate depths		Fourteen animals/ year round/ satellite-linked data recorders	Gjertz et al. (2001)
Harbor seal					North Atlantic (St. Lawrence Estuary)	Foraging (U-shaped) dives generally went to sea bottom (average depth of only 20 m); other dives were shallower (6-12 m)	24% at <1 m; 25% at 1-20 m; 51% at >20 m	Eight animals/ June-September/ time-depth recorders	Lesage et al. (1999)

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