APPLICATION FOR LETTERS OF AUTHORIZATION AND RULEMAKING UNDER SECTION 101 (a)(5)(A) OF THE MARINE MAMMAL PROTECTION ACT FOR ACTIVITIES ASSOCIATED WITH THE EMPLOYMENT OF SURVEILLANCE TOWED ARRAY SENSOR SYSTEM LOW FREQUENCY ACTIVE (SURTASS LFA) SONAR

DEPARTMENT OF THE NAVY
CHIEF OF NAVAL OPERATIONS

AUGUST 2011

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

%	Percent
≥	Greater than or equal to
<	Less than
±	Plus or minus
µ	Micro (10^{-6})
AEP	Auditory evoked potential
AIM	Acoustic Integration Model
ASW	Antisubmarine warfare
C	Celcius
CITES	Convention on International Trade in Endangered Species
CLFA	Compact low frequency active
CNO	Chief of Naval Operations
COTS	Commercial off-the-shelf
CW	Continuous wave
DASN(E)	Deputy Assistant Secretary of the Navy for Environment
dB	Decibel(s)
dB re 1 µPa @ 1 m	Decibels relative to one microPascal measured at one meter from center of acoustic source
dB re 1 µPa^2-sec	Decibels relative to one micropascal squared per second
DoN	Department of the Navy
EMCON	Emissions control
EO	Executive Order
ESA	Endangered Species Act
F	Fahrenheit
FM	Frequency modulated
FOEIS/EIS	Final Overseas Environmental Impact Statement/Environmental Impact Statement
ft	Feet
FY	Fiscal Year
HF	High frequency
HLA	Horizontal line array
hr	Hour(s)
Hz	Hertz
IUCN	International Union of Conservation of Nature

ACRONYMS AND ABBREVIATIONS

IWC	International Whaling Commission
kg	Kilogram(s)
km	Kilometer(s)
kHz	KiloHertz
kph	Kilometers per hour
kt	Knot(s)
lb	Pound(s)
LF	Low frequency
LFA	Low Frequency Active
LOA	Letter of Authorization
LFS	Low frequency sound
LTMP	Long Term Monitoring Program
m	Meter(s)
MF	Mid-frequency
MFA	Mid-frequency active
min	Minute(s)
MMPA	Marine Mammal Protection Act
MPA	Marine Protected Area
NATO	North Atlantic Treaty Organization
NDAA	National Defense Authorization Act
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
nmi	Nautical mile(s)
NMS	National Marine Sanctuary
OBIA(s)	Offshore biologically important area(s)
OEIS/EIS	Overseas Environmental Impact Statement and Environmental Impact Statement
OIC	Officer in charge
OPAREA	Operating area
Pa	Pascal
PTS	Permanent threshold shift
RL	Received level
rms	Root mean square
RV	Research vessel

ACRONYMS AND ABBREVIATIONS

sec	Second(s)
SEIS/SOEIS	Supplemental Environmental Impact Statement/Supplemental Overseas Environmental Impact Statement
SEL	Sound exposure level
SL	Source level
Sonar	SOund Navigation And Ranging
SPE	Single ping equivalent
SPL	Sound pressure level
SRP	Scientific Research Program
SURTASS	Surveillance Towed Array Sensor System
T-AGOS	Tactical-Auxiliary General Ocean Surveillance
TL	Twin line
TTS	Temporary threshold shift
U.S.	United States
U.S.C.	United States Code
USNS	United States Naval Ship
VLA	Vertical line array

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1 DESCRIPTION OF THE PROPOSED ACTIVITY

<u>*Requirement 1*</u>: *A detailed description of the specific activity or class of activities that can be expected to result in the incidental taking of marine mammals.*

1.1 INTRODUCTION

Pursuant to Section 101 (a)(5)(A) of the Marine Mammal Protection Act of 1972, as amended (MMPA;16 USC 1371), the Department of the Navy (DoN) is applying for rulemaking and Letters of Authorization (LOAs) for the employment of Surveillance Towed Array Sensor System (SURTASS) Low Frequency Active (LFA) sonar during training, testing, and routine military operations. The MMPA directs the Secretary of Commerce (Secretary) to allow, upon request, the incidental, but not intentional taking of marine mammals by U.S. citizens who engage in a specified activity (other than commercial fishing) during periods of not more than five consecutive years. The issuance occurs when the Secretary, after notice has been published in the *Federal Register* and opportunity for comment has been provided, finds that such takes will have a negligible impact on the species and stocks of marine mammals and will not have an unmitigable adverse impact on their availability for subsistence uses. Marine mammals will be harassed due to the underwater noise generated incidentally by the employment of SURTASS LFA sonar systems during at-sea operations. As a result, DoN (hereafter, the Navy) is requesting LOAs and rulemaking under the MMPA for taking of marine mammals by Level A and Level B (no lethal) harassment incidental to the employment of up to four SURTASS LFA sonar systems within restricted areas of the world's oceans for the five year period from August 2012 through August 2017.

This application for rulemaking and LOAs is the third such application the DoN has submitted to the National Marine Fisheries Service (NMFS) for employment of SURTASS LFA sonar. In 2002, NMFS issued regulations and the initial LOA (NOAA, 2002) under the MMPA Final Rule (50 CFR §216 Subpart Q) (NOAA, 2002a) for the operation of SURTASS LFA sonar on the research vessel (RV) *Cory Chouest*. The Navy requested and was issued annual LOA renewals in accordance with 50 CFR §216.189 for the remaining four years of the 2002 Final Rule for the research vessel (RV) *Cory Chouest* and USNS IMPECCABLE. In 2006, the Navy submitted its application for the second five-year Rule under MMPA (DoN, 2006) for the taking of marine mammals by Level A and Level B harassment incidental to the deployment of up to four SURTASS LFA sonar systems for military readiness activities from 16 August 2007 to 15 August 2012. NMFS published the second MMPA Final Rule in August 2007 (NOAA, 2007) for the employment of SURTASS LFA sonar, and subsequently in 2007 issued annual LOAs for sonar use on the RV *Cory Chouest,* USNS ABLE, USNS VICTORIOUS, USNS EFFECTIVE and USNS IMPECCABLE.

This application document has been prepared in accordance with applicable regulations and the MMPA, as amended by the National Defense Authorization Act (NDAA) for Fiscal Year 2004 (Public Law 108-136). The NDAA modified the MMPA by removing the ''small numbers'' and ''specified geographical region'' limitations and amended the definition of ''harassment'' as it applies to a ''military readiness activity."

The basis of this third request for rulemaking and LOAs are: (1) the analysis of spatial and temporal distributions of protected marine mammals in potential operating areas for SURTASS LFA sonar, (2) a review of activities that have the potential to affect marine mammals, and (3) a technical risk assessment to determine the likelihood of effects from use of active sonar during Navy training, testing, and routine military operations in the world's oceans, with specific geographic areas exempted from operations.

1.2 PROPOSED ACTIVITY

The proposed action is Navy's employment of up to four SURTASS LFA sonar systems in the world's non-polar oceans for military readiness activities including training, testing, and routine military operations from August 2012 through August 2017. Potential operations could occur in the Pacific, Atlantic, and Indian Oceans, and the Mediterranean Sea. The Navy will not operate SURTASS LFA sonar: (1) in Arctic and Antarctic waters; (2) in waters within 22 kilometers [km] (12 nautical miles [nmi]) of land; and (3) in offshore biologically important areas (OBIAs) for marine mammals, which are identified in this application.[1]

Nominal at-sea missions for each vessel using SURTASS LFA sonar would last up to 294 days, with 240 days of active sonar transmissions and 54 days of transit. The maximum number of actual transmission hours per vessel would not exceed 432 hours (hrs) annually.

For this application, the Navy has determined that marine mammals would be incidentally harassed by the acoustic signals transmitted during the employment of SURTASS LFA sonar during at-sea operations. The remainder of this chapter discusses the Navy's SURTASS LFA sonar operations in greater detail.

1.3 BACKGROUND

In 2003, the NDAA included amendments to the MMPA that apply where a "military readiness activity" is concerned. The term "military readiness activity" is defined in Public Law 107-314 (16 U.S.C. §703 note) to include all training and operations of the Armed Forces that relate to combat; and the adequate and realistic testing of military equipment, vehicles, weapons and sensors for proper operation and suitability for combat use. The NMFS and Navy have established that the Navy's testing and training operations for SURTASS LFA sonar constitute military readiness activities as defined by public law and constitute "adequate and realistic testing of military equipment, vehicles, weapons and sensors for proper operation and suitability for combat use" (NOAA, 2002).

During employment of the SURTASS LFA sonar system, acoustic signals are introduced into the ocean environment that could potentially affect the marine environment. As a result, the Navy conducted analyses relevant to the potential environmental effects of using the SURTASS LFA sonar system and prepared a Final Overseas Environmental Impact Statement and Environmental Impact Statement (FOEIS/EIS) (DoN, 2001) and a Supplemental Environmental Impact Statement (SEIS) (DoN, 2007). Concurrent with the development of this application, the Navy has completed a second Supplemental EIS/Supplemental OEIS (SEIS/SOEIS) (DoN, 2011). The DoN is the lead agency and NMFS is the cooperating agency for the preparation of these documents, which are being prepared in accordance with the requirements of the National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. 4321 et seq.) and Executive Order (EO) 12114, Environmental Affects Abroad for Major Federal Actions. For SURTASS LFA sonar, EO 12114 applies to environmental effects outside U.S. maritime boundaries, including U.S. territories and possessions.

Due to concerns raised during past litigation over employment of the SURTASS LFA sonar system and to support issuance of a third five-year Rule under the MMPA for employment of SURTASS LFA sonar systems, the Deputy Assistant Secretary of the Navy for Environment (DASN(E)) determined on 14 November 2008 that the purposes of the NEPA and EO 12114 would be furthered by the preparation of an additional supplemental analysis related to the employment of the system. This second SEIS/SOEIS, prepared in accordance with NEPA and EO 12114, was initiated to provide further analysis of potential additional global OBIAs (located at distances greater than 22 km [12 nmi] from shore); of the practicality

1 Although not germaine to this LOA and rulemaking application, an additional geographic restriction is in place for the employment of SURTASS LFA sonar. The sound field produced by the sonar cannot exceed 145 dB SPL in the vicinity of known human dive sites (most sites frequented by recreational divers generally are shallower than 40 m [130 ft]) to protect human divers.

of altering the size of the coastal standoff range (currently 22 km [12 nmi] from shore) for use of SURTASS LFA sonar where the continental shelf extends further than the current standoff range; and further analysis of the potential for cumulative impacts involving other active sonar sources.

1.4 PURPOSE AND NEED FOR SURTASS LFA SONAR

The Navy's primary mission is to maintain, train, equip, and operate combat-ready naval forces capable of accomplishing American strategic objectives, deterring maritime aggression, and maintaining freedom of the seas. This mission is mandated by Federal law (Title 10 U.S.C. §5062), which ensures the readiness of the U.S. naval forces. The Secretary of the Navy and Chief of Naval Operations (CNO) have established that anti-submarine warfare (ASW) is a critical part of the Navy's mission, requiring unfettered access to both the high seas and littorals[2]. To be prepared for all potential threats, the Navy must maintain ASW core competency through continual training in open-ocean and littoral environments.

ASW is challenged by the increased difficulty in locating undersea threats solely by using the passive acoustic technologies that were effective previously, due to the advancement and use of quieting technologies in diesel-electric and nuclear submarines. The range at which U.S. ASW assets are able to identify submarine threats is decreasing, and at the same time, improvements in torpedo design are extending the effective weapons range of subsea threats (Benedict, 2005). Maritime military strategies rely heavily on quiet submarines to patrol the littorals, blockade strategic choke points, and stalk aircraft carrier battle groups (Goldstein and Murray, 2003).

One of the ways the Navy has addressed the changing requirements for ASW readiness was by developing SURTASS LFA sonar. SURTASS LFA sonar is able to reliably detect quieter and harder-to-find submarines at long range, before these vessels can get within their effective weapons range to launch missiles or torpedoes against U.S. ships or land targets. SURTASS LFA sonar operates day and night in a variety of weather conditions. The active acoustic component in the SURTASS LFA sonar is an important augmentation to passive and tactical systems, as its long-range detection capabilities can effectively counter the threat to the U.S. Navy and national security posed especially by quiet, diesel submarines.

1.5 SURTASS LFA SONAR TECHNOLOGY

SURTASS LFA sonar systems are long-range sensors that operate in the low frequency (LF) band (i.e., below 1,000 Hertz [Hz]) and include both active and passive acoustic components (Figure 1). SONAR is an acronym for SOund NAvigation and Ranging, and its definition includes any system that uses underwater sound, or acoustics, for observations, monitoring, and communications. Sonar systems are used for many purposes, ranging from commercial off-the-shelf (COTS) "fish finders" to military ASW systems for detection and classification of submarines.

The passive component, SURTASS, is a towed horizontal line array detection system that uses hydrophones to detect sound emitted or reflected from submerged targets. Passive sonar is a one-way transmission of sound waves traveling through the water from the source to the receiver and is basically the same as people hearing sounds that are created by another source and transmitted through the air to the ear. The active component of the system, LFA, is comprised of a set of acoustic transmitting source elements suspended by cable beneath ocean surveillance ships. Active sonar detects objects by creating a sound pulse or "ping" that is transmitted through the water and reflects off the target, returning in the form of an echo. This is a two-way transmission (source to reflector to receiver). Echolocation, by which some marine mammals locate prey and navigate, is a form of active sonar.

2 The Navy defines "littoral" as the region that horizontally encompasses the land/water mass interface from 50 statute miles (80 km) ashore to 200 nmi (370 km) at sea; this region extends vertically from the bottom of the ocean to the top of the atmosphere and from the land surface to the top of the atmosphere (Naval Oceanographic Office, 1999). The common meaning of littoral pertains to the shore or a coastal region, while the marine science definition refers to the shallow-water zone between low- and high-tide.

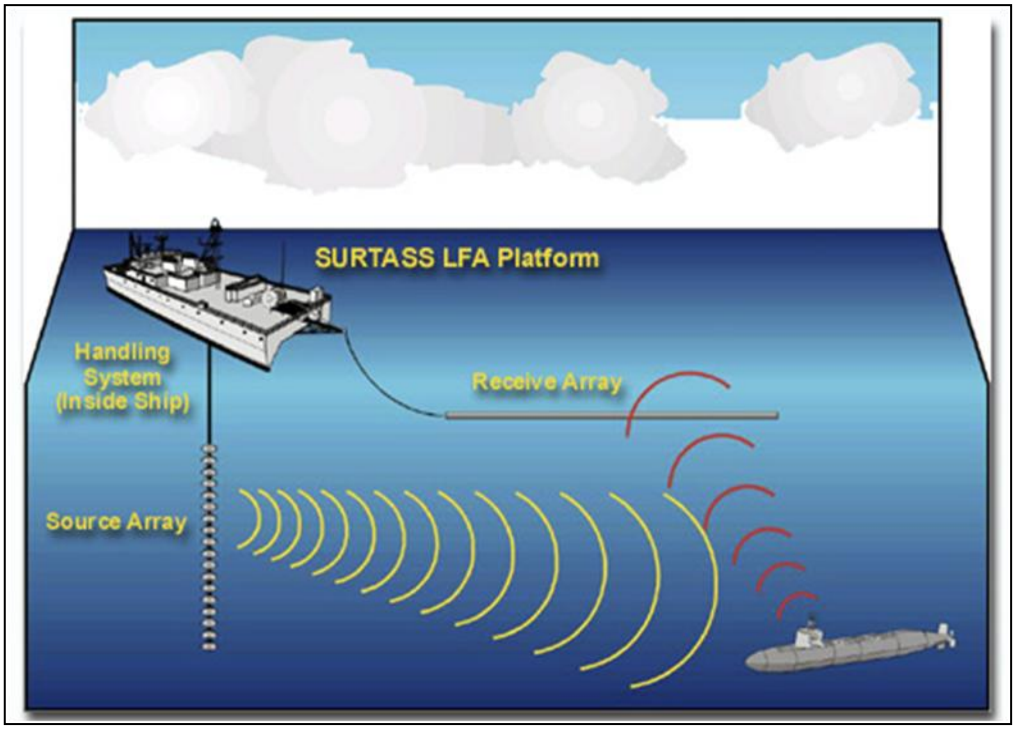

Figure 1. SURTASS LFA sonar systems showing the active (source array) and passive (receive array) components.

SURTASS LFA sonar systems operate within the frequency range of 100 to 500 Hz. The LFA sonar component is an augmentation to the SURTASS component and is planned for use when passive system performance is inadequate.

LFA systems were initially installed on two SURTASS ocean surveillance ships, RV *Cory Chouest*, which was retired in 2008, and USNS IMPECCABLE (Tactical-Auxiliary General Ocean Surveillance [T-AGOS 23]). As current and future undersea warfare requirements continue to transition to littoral ocean regions, the introduction of a compact active system deployable on SURTASS ships was needed. This system upgrade is known as Compact LFA, or CLFA. CLFA consists of smaller, lighter-weight source elements than the current LFA system and is compact enough to be installed on the VICTORIOUS Class platforms. The initial CLFA installation was completed on the USNS ABLE (T-AGOS 20) in 2008 and at-sea-testing commenced in August 2008. CLFA improvements include:

- Operational frequency, within the 100 to 500 Hz range, matched to shallow water environments with little loss of detection performance in deep water environments,
- Improved reliability and ease of deployment, and
- Lighter-weight design (mission weight of 64,410 kilograms (kg) [142,000 pounds {lb}] vice 155,129 kg [324,000 lb] mission weight of LFA).

At present, one SURTASS LFA sonar system is onboard USNS IMPECCABLE and one SURTASS CLFA sonar system is onboard the USNS ABLE (T-AGOS 20). Two additional CLFA systems are planned for the T-AGOS 19 Class of surveillance ships (Figure 2). Late in fiscal year (FY) 2011, the CLFA system onboard the USNS EFFECTIVE (T-AGOS 21) is scheduled to commence at sea testing and training. The CLFA system to be installed onboard the USNS VICTORIOUS (T-AGOS 19) is scheduled for at sea testing and training in FY 2012 as authorized in the 2007 regulations. For this application for rulemaking and LOAs, no more than four systems are expected to be in use through FY 2017.

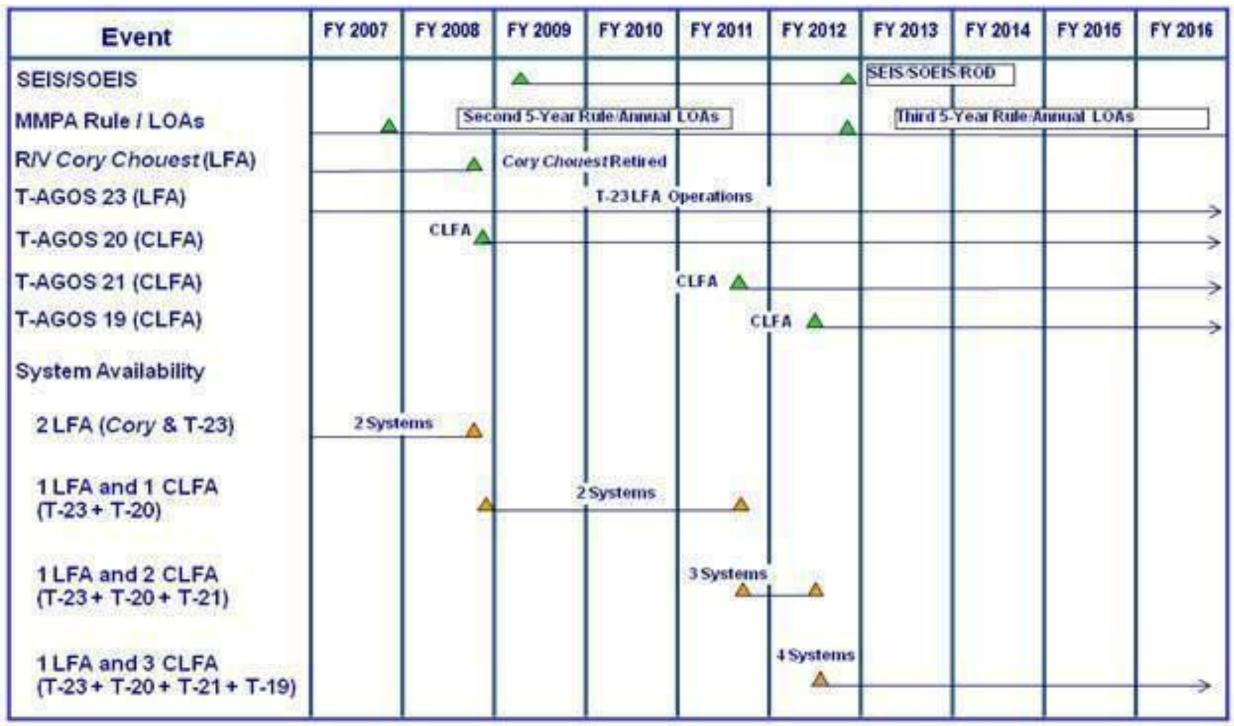

Figure 2. Projected LFA and CLFA sonar systems availability.

1.5.1 ACTIVE ACOUSTIC SYSTEM

The operational characteristics of the active component of CFLA are comparable to the existing LFA systems. The characteristics and operating features of the active component of LFA are:

- The source is a vertical line array (VLA) of up to 18 source projectors suspended beneath the vessel. LFA's transmitted beam is omnidirectional (360 degrees) in the horizontal, with a narrow vertical beamwidth that can be steered above or below the horizontal.
- The source frequency is between 100 and 500 Hz. A variety of signal types can be used, including continuous wave (CW) and frequency-modulated (FM) signals.
- The source level (SL) of an individual source projector of the SURTASS LFA sonar array is approximately 215 decibels (dB) sound pressure level (SPL) or less. As measured by SPL, the sound field of the array can never be higher than the SL of an individual source projector.
- The typical LFA signal is not a constant tone, but rather a transmission of various waveforms that vary in frequency and duration. A complete sequence of sound transmissions is referred to as a wavetrain (also known as a "ping"). These wavetrains last between 6 and 100 seconds with an average length of 60 seconds. Within each wavetrain the duration of each continuous frequency sound transmission is no longer than 10 seconds.
- Average duty cycle (ratio of sound "on" time to total time) is less than 20%. The typical duty cycle, based on historical LFA operational parameters (2003 to 2009), is nominally 7.5 to 10%.
- The time between wavetrain transmissions is typically from 6 to 15 minutes.

Therefore, the potential impacts from CLFA are expected to be similar to, and not greater than, the effects from the existing SURTASS LFA systems.

References to Underwater Sound Levels
• References to underwater sound pressure level (SPL) in this document are values given in decibels (dBs) and are assumed to be standardized at 1 microPascal at 1 m (dB re 1 µPa at 1 m [rms]) for source level (SL) and dB re 1 µPa (rms) for received level (RL), unless otherwise stated (Urick, 1983; ANSI, 2006).
• Underwater sound exposure level (SEL) is a measure of energy, specifically the squared instantaneous pressure integrated over time and expressed as an equivalent one-second in duration signal, unless otherwise stated; the appropriate units for SEL are dB re 1 μPa^2-sec (Urick, 1983; ANSI, 2006; Southall et al., 2007).
• The term "Single Ping Equivalent" (SPE) is an intermediate calculation for input to the risk continuum that was used in the NEPA and EO 12114 documentation for SURTASS LFA sonar usage. SPE accounts for, or sums, the energy of all of the LFA acoustic transmissions that a modeled animal receives during an entire LFA mission (modeled for operations from 7 to 20 days). Calculating the potential risk from SURTASS LFA is a complex process (see Appendix C of the Draft SEIS/SOEIS [DoN, 2011] for details). As referenced in the SURTASS LFA sonar documentation, SPE does not have a straightforward, identified unit. SPE levels will be expressed as "dB SPE" in this document, as they have been in the SURTASS LFA sonar OEIS/FEIS and SEIS documents (DoN, 2001 and 2007).

1.5.2 PASSIVE ACOUSTIC SYSTEM

The SURTASS, passive, or listening, part of the system detects returning echoes from submerged objects, such as threat submarines, through the use of hydrophones. These devices transform mechanical energy (received acoustic sound waves) to an electrical signal that can be analyzed by the processing system of the sonar. Advances in passive acoustic technology have led to the development of SURTASS Twin-line (TL-29A) horizontal line array (HLA), a shallow water variant of the single line SURTASS system. TL-29A consists of a "Y" shaped array with two apertures. The array is approximately 1/5th the length of a standard SURTASS array, or approximately 305 m (1,000 ft) long. The TL-29A delivers enhanced capabilities, such as its ability to be towed in shallow water environments in the littoral zones, to provide significant directional noise rejection, and to resolve bearing ambiguities without having to change vessel course. The SURTASS TL-29A HLA provides improved littoral capability.

The passive capability of the USNS IMPECCABLE (T-AGOS 23) was recently upgraded with the installation of the TL-29A array. The three CLFA VICTORIOUS Class vessels are, or will be, outfitted with the newer SURTASS TL-29A passive arrays.

The SURTASS LFA sonar vessel typically maintains a speed of at least 5.6 kilometers per hour (kph) (3 knots [kt]) through the water in order to tow the HLA. The return signals, which are usually below background or ambient noise level, are then processed and evaluated to identify and classify potential underwater threats.

2 DURATION AND LOCATION OF SURTASS LFA SONAR USE

Requirement 2: Date(s) and duration of such activity and the specific geographic region where it will occur.

2.1 DURATION

Due to uncertainties in the world's political climate, a detailed account of future operating locations and conditions for SURTASS LFA sonar cannot be predicted. However, for analytical purposes, a nominal annual deployment schedule and operational concept were developed, based on actual LFA operations conducted since January 2003 and projected Navy requirements. The SURTASS LFA sonar vessels typically operate independently but may operate in conjunction with other naval air, surface, or submarine assets. The vessels generally travel in straight lines or racetrack patterns depending on the operational scenario.

Annually, each vessel will be expected to spend approximately 54 days in transit and 240 days performing active operations (Table 1). Between missions, an estimated total of 71 days per year will be spent in port for upkeep and repair to maintain both the material condition of the vessel and its systems, and the morale of the crew. The actual number and length of the individual missions within the 240 days are difficult to predict, but the maximum number of actual transmission hours per vessel per year will not exceed 432 hours (hrs).

Table 1. Nominal annual deployment schedule for SURTASS LFA sonar vessels.

UNDERWAY—MISSION	DAYS	NOT UNDERWAY	DAYS
Transit	54	In-Port Upkeep	40
Active Operations (432 hours transmissions per vessel based on 7.5% duty cycle[3])	240	Regular Overhaul	31
Total Underway	294	Total Not Underway	71
Total			365

2.2 POTENTIAL SURTASS LFA SONAR OPERATING AREAS

As an integral part of the MMPA permitting process, as well as for the NEPA process, the Navy must anticipate, or predict, where they have to operate in the next five years. Naval forces are presently operating in several areas strategic to U.S. national and international interests, including areas in the Mediterranean Sea, Indian Ocean, Persian Gulf, and the Pacific Rim. National security needs may dictate that many of these operational areas will be close to ports and choke points, such as entrances to straits, channels, and canals. Also, many future naval conflicts are likely to occur within littoral or coastal areas.

3 Note: 7.5% duty cycle is based on historical SURTASS LFA sonar operating parameters, which include downtime for:

- Corrective maintenance (equipment casualties or system failures)
- Preventive maintenance (database maintenance, daily archive, tow-point changes, and system upgrades)
- Ship re-positioning
- De-conflict interference with other naval sensor systems
- EMCON (emission control) restrictions during naval operations and exercises.

The Navy must balance national security needs with environmental requirements and impacts, while protecting both our freedom and the world's natural resources.

Due to the temporal limit (no more than five years) on NMFS' regulatory authority for regulations and LOAs for regulations and LOAs under the MMPA process and the difficulty in predicting potential future operations for SURTASS LFA sonar, locations and conditions have only been projected for the future five-year period from 2012 through 2017. Potential operations for SURTASS LFA sonar vessels over these five years, based on current operational requirements, will most likely include areas located in the Pacific, Indian, and Atlantic Oceans and Mediterranean Sea but will exclude the polar regions of the world (Figure 3). Polar waters are excluded from operational planning because of the inherent inclement weather conditions and the navigational and operational (equipment) danger that icebergs pose to SURTASS LFA sonar vessels. To reduce adverse effects on the marine environment, the operation of SURTASS LFA sonar also will not be conducted within a specific geographic range of land and in OBIAs. Routine training and testing of SURTASS LFA sonar and participation in military operations will potentially take place within any of the operating areas.

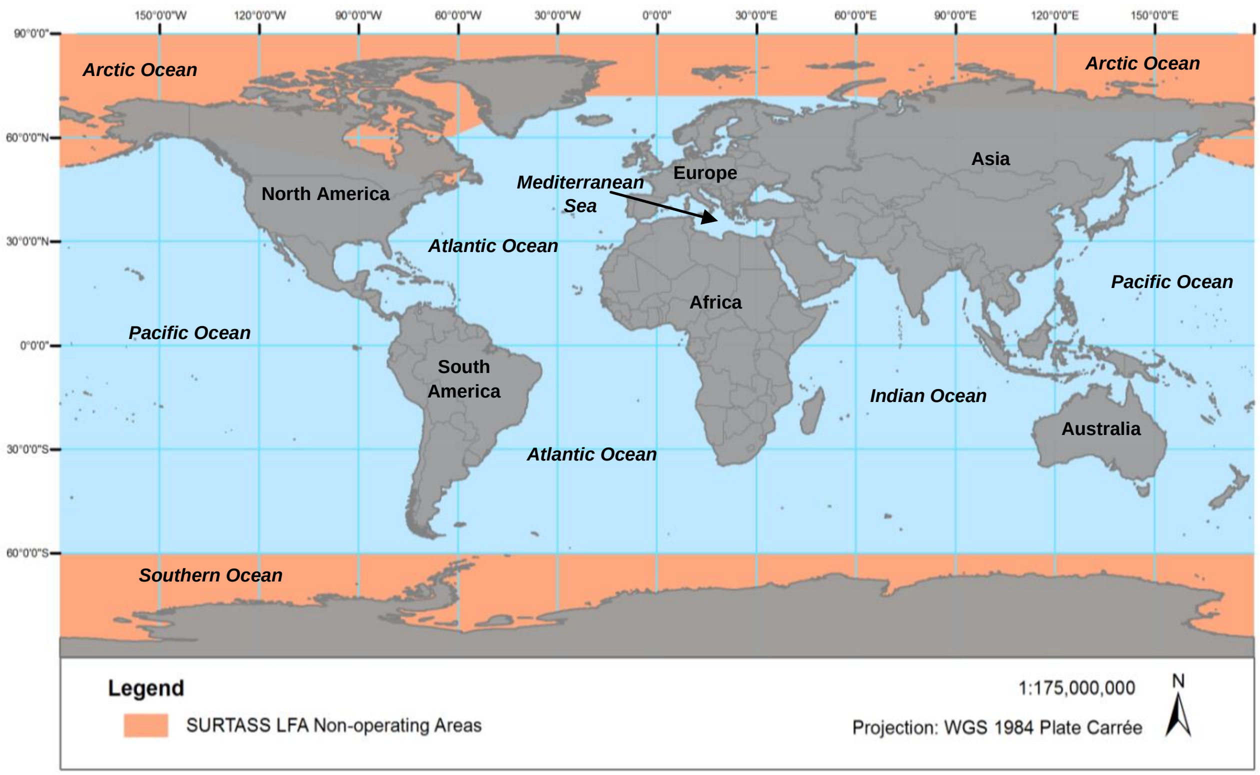

Figure 3. Potential areas of operation for SURTASS LFA sonar.

2.2.1 GEOGRAPHIC RESTRICTIONS—COASTAL STANDOFF RANGE

Based on the analyses presented in SURTASS LFA sonar NEPA documents (DoN, 2001, 2007, and 2011), geographic restrictions, known as the "coastal standoff ranges", to the deployment of SURTASS LFA sonar have been developed to provide the lowest risk to marine mammals. During SURTASS LFA operations, the sound field produced by the sonar must be below 180 dB SPL within 22 km (12 nmi) of any coastline.

The Navy also considered increasing the coastal standoff range where the continental shelf break[4] is further offshore than 22 km (12 nmi); the most current OBIA analysis has considered the biological importance of areas for marine mammals outside the current 22 km (12 nmi) coastal standoff range.

2.2.2 Geographic Restrictions—Offshore Biologically Important Areas (OBIAs) for Marine Mammals

SURTASS LFA sonar systems have the potential to adversely affect marine animals. In the past, Navy has applied for, and NMFS has issued, MMPA regulations and LOAs that allow for the incidental taking of marine mammals, while prescribing measures to minimize impacts. To meet the least practicable adverse impacts to marine mammals under Section 101(a)(5)(A) of the MMPA, NMFS and the Navy developed mitigation measures to reduce the potential for adverse impacts. Part of the comprehensive suite of mitigation measures used in previous authorizations to minimize impacts and adverse effects to marine mammals is the concept of OBIAs. NMFS' 2007 regulations for the operation of SURTASS LFA sonar required the Navy to refrain from operating the SURTASS LFA sonar within any OBIA during biologically important seasons, and required that the SURTASS LFA sonar vessel ensured that the 180 dB re 1 µPa (root mean square [rms]) isopleth remains at least 1 km (0.54 nmi) seaward of the outer perimeter of the OBIA (NOAA, 2007). For the use of SURTASS LFA sonar under the 2007 regulations, OBIAs were defined as those areas of the world's oceans outside of the geographic stand-off range of a coastline (i.e., 22 km [12 nmi]) where marine animals of concern (those animals listed under the Endangered Species Act of 1973 (ESA; 16 U.S.C. § 1531 et seq.) and/or marine mammals) congregate in high densities to carry out biologically important activities. These areas include migration corridors; breeding and calving grounds; and feeding grounds.

Under the 2007 Rule (NOAA, 2007), 10 OBIAs were designated for marine mammals during the employment of SURTASS LFA sonar. However, one of the goals of the most recent SURTASS LFA sonar SEIS/SOEIS (DoN, 2011) was the reassessment and definition of additional OBIAs in regions of the world where the Navy intends to use the SURTASS LFA sonar systems. The process of identifying potential marine mammal (MM) OBIAs involved an assessment by both the NMFS and the Navy to identify the areas that met the selection criteria for an OBIA. For those areas that were determined to meet the biological criteria, the Navy also performed a practicability assessment.

To assist in the process of identifying potential LFA OBIAs for marine mammals, NMFS convened an expert review panel of independent scientists knowledgeable about potentially affected marine mammal habitats. This panel consisted of eight subject matter experts (SME), each with specific expertise in geographic regions including the Atlantic Ocean, Pacific Ocean, Mediterranean Sea, Indian Ocean/Southeast Asia, and East Africa. The SMEs provided analysis of potential marine mammal OBIAs in regions of the world where the Navy potentially could use the SURTASS LFA sonar systems.

NMFS developed screening criteria to determine an area's eligibility to be considered as a nominee as a MM OBIA. These OBIA criteria include:

- Outside of coastal standoff distance and non-operational areas (i.e., >22 km [12 nmi] from shore and not in polar regions),
- Biological importance
    - High density of marine mammals,
    - Known, defined breeding/calving grounds, foraging grounds, and migration routes, and
    - Small, distinct populations with limited distributions.

NMFS initially considered more than 400 areas of the world's oceans as potential MM OBIAs. After compiling the recommendations of the SME panel and further assessing the potential areas, NMFS and Navy ultimately concluded that there was an adequate scientific basis, which included an evaluation of

4 The continental shelf break is the boundary of the continental margin where the continental shelf transitions to the continental slope and where an abrupt increase in the gradient (slope) of the seafloor results in a rapid increase in depth.

the significant marine mammal species' distribution, density, and important biological activities in the area, to designate 22 OBIAS for SURTASS LFA sonar for the Draft SEIS/SOEIS. Part of this evaluation also included an assessment of the best hearing sensitivity associated with the significant marine mammals, as only baleen whales, which are LF hearing specialists (<1,000 Hz), have shown minor but short-term behavioral responses within a limited range of a LFA source (Miller et al., 2000; Croll et al., 2001; Fristrup et al, 2003)[5]. However, after subsequently considering operational needs and practicability, the Navy is proposing to apply the mitigation discussed later in this application to 21 of these OBIAs for SURTASS LFA sonar (Table 2). A detailed description of the OBIA derivation process, assessment conclusions, and specific OBIA boundary coordinates may be found in the Draft SEIS/SOEIS (DoN, 2011).

Implementation of the LFA MM OBIA restrictions is part of the overall mitigation and monitoring program for the continued use of SURTASS LFA sonar. These OBIAs, as part of the suite of overall mitigation measures proposed for the employement of SURTASS LFA sonar, will reduce incidental takings by the sonar and, consistent with the 2007 Rule (NOAA, 2007), are not intended to apply to other Navy activities and sonar operations.

2.2.3 POTENTIAL OPERATING AREAS—MODELED SITES

To achieve the purpose for which SURTASS LFA sonar was developed, the sonar must operate near potential ASW adversaries. However, the environmental impacts possibly resulting from the operation of the sonar in strategic areas must also be considered. Thus, a process that intertwines these mutual goals of minimizing the potential for environmental effects while operating the sonar in relevant areas is necessary. The Navy and NMFS have developed a joint, scientifically-based process to select potential relevant operating areas for SURTASS LFA sonar while considering environmental impacts that has culminated in NMFS' issuance of annual LOAs. In addition, the Navy is required to develop an annual process, in consultation with NMFS, which identifies, through LOA application procedures, the locations that the Navy intends to operate within that year. Annual additional analyses (including acoustic modeling) are undertaken, if it is deemed necessary (e.g., updated marine mammal distribution or density data available for potential operating areas).

It is infeasible to analyze all worldwide potential operating or mission areas of SURTASS LFA sonar for all marine species and stocks for all seasons. Yet, designation of specific oceanic areas are necessary to conduct the acoustic impact modeling that will predict the potential effects of SURTASS LFA sonar operations on marine species. For this purpose, in the FOEIS/EIS, 31 worldwide potential sites and seasons, selected solely for their high densities of marine mammals during biologically important times of year (e.g., foraging or calving areas and seasons), were modeled and analyzed (DoN, 2001). The analyses of these 31 sites used very conservative parameters, such that the results of the FOEIS/EIS underwater acoustic modeling analyses remain valid. The nine additional potential operating sites that were modeled and analyzed in the FSEIS (DoN, 2007) were selected due to their location in areas of the

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5 Clark and Southall (2009) noted in a white paper on mid-frequency and/or high-frequency (MF/HF) odontocete hearing specialists and responses to LFA sounds that the LFA source is well below the range of best hearing sensitivity for MF/HF odontocete hearing specialists, based on the fairly extensive body of laboratory measurements. Clark and Southall (2009) further reported that during the 1997 to 1998 SURTASS LFA Sonar Low Frequency Sound Scientific Research Program (LFS SRP), numerous odontocete and pinniped species (i.e., MF and HF hearing specialists) were sighted in the vicinity of the sound exposure tests and showed no immediately obvious responses or changes in sighting rates as a function of source conditions. Consequently, Clark and Southall (2009) concluded that none of these species had any obvious behavioral reaction to LFA signals at received levels similar to those that produced only minor but short-term behavioral responses in the baleen whales (i.e., LF hearing specialists). Under certain conditions during the LFS SRP, some of the focal baleen whale individuals within a limited range of the LFA source responded to the LFA sonar signal but returned to their normal activities within a short period. Thus, for odontocetes, the chances of injury and/or significant behavioral responses to SURTASS LFA sonar are very low to negligible given MF/HF specialists observed lack of response to LFA sounds during the LFS SRP, their natural acoustic ecologies, and the MF/HF frequencies to which these animals are adapted to hear and produce (Clark and Southall, 2009).

Table 2. Proposed LFA OBIAs for marine mammals.

OBIA Number	Area Name	Water Body	Significant Marine Mammal Species	Seasonal Restrictions
1	Georges Bank	Northwest Atlantic Ocean	North Atlantic right whale	Year-round
2	Roseway Basin Right Whale Conservation Area	Northwest Atlantic Ocean	North Atlantic right whale	Canadian Restriction: June through December
3	Great South Channel, U.S. Gulf of Maine, and Stellwagen Bank NMS[6]	Northwest Atlantic Ocean/ Gulf of Maine	North Atlantic right whale	January 1 to November 14
4	Southeastern U.S. Right Whale Seasonal Habitat	Northwest Atlantic Ocean	North Atlantic right whale	15 November to 15 April
5	North Pacific Right Whale Critical Habitat	Northeastern Pacific Ocean/Gulf of Alaska and Bering Sea	North Pacific right whale	March through August
6	Silver Bank and Navidad Bank	Northwestern Atlantic Ocean/Caribbean Sea	Humpback whale	December through April
7	Coastal Waters of Gabon, Congo and Equatorial Guinea	Southeastern Atlantic Ocean	Humpback whale and Blue whale	June through October
8	Patagonian Shelf Break	Southwestern Atlantic Ocean	Southern elephant seal	Year-round
9	Southern Right Whale Seasonal Habitat	Southwestern Atlantic Ocean	Southern right whale	May through December
10	Central California National Marine Sanctuaries	Northeastern Pacific Ocean	Blue whale and humpback whale	June thru November
11	Antarctic Convergence Zone	Southern Ocean	Blue whale, fin whale, sei whale, minke whale, humpback whale, and Southern right whale	October through March
12	Piltun and Chayvo Offshore Feeding Grounds—Sea of Okhotsk	Northwestern Pacific Ocean/Sea of Okhotsk	Western Pacific gray whale	June through November
13	Coastal Waters off Madagascar	Western Indian Ocean	Humpback whale and blue whale	July through September for humpback whale breeding November through December for migrating blue whales
14	Madagascar Plateau, Madagascar Ridge, and	Western Indian Ocean	Pygmy blue whale, humpback whale, and	November through December

6 The boundary of OBIA #3 encompasses the northern critical habitats of the North Atlantic right whale, Stellwagen Bank National Marine Sanctuary, and areas within the Gulf of Maine.

Table 2. Proposed LFA OBIAs for marine mammals.

OBIA Number	Area Name	Water Body	Significant Marine Mammal Species	Seasonal Restrictions
	Walters Shoal		Bryde's whale	
15	Ligurian-Corsican-Provençal Basin and Western Pelagos Sanctuary	North-central Mediterranean Sea	Fin whale	July to August
16	Hawaiian Islands Humpback Whale NMS—Penguin Bank	North-Central Pacific Ocean	Humpback whale	November through April
17	Costa Rica Dome	Eastern Tropical Pacific Ocean	Blue whale and humpback whale	Year-round
18	Great Barrier Reef Between 16°S and 21°S	Coral Sea/Southwestern Pacific Ocean	Humpback whale and dwarf minke whale	May through September
19	Bonney Upwelling	Eastern Indian Ocean	Blue whale, pygmy blue whale, and Southern right whale	December through May
20	Northern Bay of Bengal and Head of Swatch-of-No-Ground (SoNG)	Bay of Bengal/Northern Indian Ocean	Bryde's whale (small form)	Year-round
21	Olympic Coast: The Prairie, Barkley Canyon, and Nitnat Canyon	Northeastern Pacific Ocean	Humpback whale	Olympic National Marine Sanctuary: December, January, March, and May The Prairie, Barkley Canyon, and Nitnat Canyon: June to September

Pacific Rim that were pertinent to U.S. national security interests. In addition to updating the 11 operating sites selected previously for relevance to national security for the current LOAs and this application's analysis, 8 more potential sites have been analyzed in areas strategic to U.S. national security interests. Thus, 19 potential sites for the operation of SURTASS LFA sonar were modeled and analyzed for the Draft SEIS/SOEIS (DoN, 2011) and this document (Table 3). In total, 50 potential operating sites for SURTASS LFA sonar, for which underwater acoustic modeling of potential impacts to marine mammals have been performed, provide the foundation for the analysis of potential effects of SURTASS LFA sonar operations on the overall marine environment and for the annual LOA application process.

Table 3. Potential SURTASS LFA sonar operating areas (OPAREAs), location, and representative season that were modeled for the Draft SEIS/OEIS (DoN, 2011).

OPAREA	Site	Modeled Season	Location (Latitude/ Longitude)	Remarks
1	East of Japan	Summer	38°N/148°E	
2	North Philippine Sea	Fall	29°N/136°E	
3	West Philippine Sea	Fall	22°N/124°E	
4	Offshore Guam	Summer / Fall	11°N/145°E	Mariana Islands Range Complex (outside Mariana Trench)
5	Sea of Japan	Fall	39°N/132°E	
6	East China Sea	Summer	26°N/125°E	
7	South China Sea	Fall	21°N/119°E	
8	NW Pacific 25° to 40°N	Summer	30°N/165°E	
9	NW Pacific 10° to 25°N	Winter	15°N/165°E	
10	Hawaii North	Summer	25°N/158°W	Hawaii Range Complex
11	Hawaii South	Spring/Fall	19.5°N/158.5°W	Hawaii Range Complex
12	Offshore Southern California	Spring	32°N/120°W	SOCAL Range Complex
13	Western Atlantic (off Florida)	Winter	30°N/78°W	AFAST Study Area (Jacksonville OPAREA)
14	Eastern N Atlantic	Summer	56.5°N/10°W	NW Approaches
15	Mediterranean Sea—Ligurian Sea	Summer	43°N/8°E	
16	Arabian Sea	Summer	20°N/65°E	
17	Andaman Sea	Summer	7.5°N/96°E	Approaches to Strait of Malacca
18	Panama Canal	Winter	5°N/81°W	Western Approach
19	Northeast Australian Coast	Spring	23°S/155°E	

3 MARINE MAMMALS

<u>Requirement 3</u>: The species and numbers of marine mammals likely to be found within an activity area.

To establish the marine mammal species or stocks potentially affected by SURTASS LFA sonar operations, two essential screening criteria were applied: the species or stocks had to occur at least seasonally in a potential operating area during the same time of year as the SURTASS LFA sonar would operate and had to possess sensory organs or tissues that allow the animals to perceive the low frequency (LF) sounds produced by the sonar. Only those species of marine mammals meeting these criteria are considered further in this application.

In cases where direct evidence of acoustic sensitivity to LF or any other frequency range is lacking for a species, reasonable indirect evidence was used to support the evaluation (e.g., there is no direct evidence that a species hears LF sound but good evidence exists that the species produces LF sound). In cases where important biological information was not available or was insufficient for one species but data were available for a related species, the comparable data were used. Additional attention was given to species with either special protected stock status or limited potential for reproductive replacement in the event of mortality.

3.1 MARINE MAMMAL SPECIES OCCURRENCE

Ninety-four species or stocks of marine mammals capable of perceiving LF sounds potentially occur in the ocean areas in which SURTASS LFA sonar may operate. These species include 12 species of mysticete (baleen) whales, 58 species of odontocete (toothed) whales, 14 species of otariid pinnipeds, and 10 species of phocid pinnipeds (Table 4). Some of these species are only found seasonally in the potential SURTASS LFA sonar operating areas while others occur year-round. Resources such as published scientific literature and AquaMaps (Kaschner et al., 2008; http://www.aquamaps.org/search.php) were utilized to establish which marine mammals potentially occurred in each operating area. Of the 94 possible marine mammal species or stocks, 19 are listed as threatened or endangered under the ESA. Due to the coastal standoff and OBIA geographic restrictions on the deployment of SURTASS LFA sonar, coastally-occurring and nearshore species such as sirenians, mustelids, river dolphins, and others are not included in the underwater acoustic risk assessment completed for SURTASS LFA sonar.

3.2 MARINE MAMMAL ABUNDANCE AND DENSITY ESTIMATES

For this LOA application and the Draft SEIS/SOEIS (DoN, 2011), risk to the possible 94 marine mammal species or stocks associated with the transmission of LF sound was derived for 19 potential SURTASS LFA sonar operating areas (Table 3). Although the distribution of many marine mammal species is irregular and highly dependent upon geography, oceanography, and seasonality, density and abundance estimates for each marine mammal species occurring in an activity area are critical components of the analytical estimation methodology to assess risk to marine mammal populations from activities occurring in the marine environment.

The process for developing density and abundance estimates for every species possibly occurring in the potential sonar operating areas was a multi-step procedure that utilized data with the highest degree of fidelity as a first step. Direct estimates from line-transect surveys that occurred in or near each of the 19 model sites were utilized first (e.g., Barlow, 2006). For the majority of marine mammal species or species, stocks, or species groups, abundance estimates were available for each of the 19 operating areas that were modeled and analyzed (Table 5). However, density estimates require more sophisticated sampling

Table 4. Marine mammal species potentially occurring in SURTASS LFA sonar operating areas and their status under the Endangered Species Act (ESA).

FAMILY	SPECIES	ESA STATUS
Mysticetes		
Balaenopteridae	Blue whale (*Balaenoptera musculus)*	Endangered
	Fin whale (*Balaenoptera physalus)*	Endangered
	Sei whale (*Balaenoptera borealis*)	Endangered
	Bryde's whale (*Balaenoptera edeni)*	
	Minke whale (*Balaenoptera acutorostrata)*	
	Humpback whale (*Megaptera novaeangliae*)	Endangered
Balaenidae	Bowhead whale (*Balaena mysticetus*)	Endangered
	North Atlantic right whale (*Eubalaena glacialis*)	Endangered
	North Pacific right whale (*Eubalaena japonica*)	Endangered
	Southern right whale (*Eubalaena australis*)	Endangered (foreign)
Neobalaenidae	Pygmy right whale (*Caperea marginata*)	
Eschrictiidae	Gray whale (*Eschrichtius robustus*)	Endangered (Only Western Pacific population)
Odontocetes		
Physeteridae	Sperm whale (*Physeter macrocephalus*)	Endangered
Kogiidae	Pygmy sperm whale (*Kogia breviceps*)	
	Dwarf sperm whale (*Kogia sima*)	
Ziphiidae	Baird's beaked whale (*Berardius bairdii)*	
	Arnoux's beaked whale (*Berardius arnuxii)*	
	Shepherd's beaked whale (*Tasmacetus sheperdii*)	
	Cuvier's beaked whale (*Ziphius cavirostris*)	
	Northern bottlenose whale (*Hyperodon ampullatus*)	
	Southern bottlenose whale (*Hyperodon planifrons)*	
	Longman's beaked whale (*Indopacetus pacificus*)	
	Andrew's beaked whale (*Mesoplodon bowdoini*)	
	Blainville's beaked whale (*Mesoplodon densirostris)*	
	Gervais' beaked whale (*Mesoplodon europaeus)*	
	Ginkgo-toothed beaked whale (*Mesoplodon ginkgodens)*	
	Gray's beaked whale (*Mesoplodon grayi)*	
	Hector's beaked whale (*Mesoplodon hectori)*	
	Hubbs beaked whale (*Mesoplodon carhubbsi)*	
	Perrin's beaked whale (*Mesoplodon perrini)*	
	Pygmy beaked whale (*Mesoplodon peruvianus)*	
	Sowerby's beaked whale (*Mesoplodon bidens)*	
	Spade-toothed beaked whale (*Mesoplodon traversii)*	
	Stejneger's beaked whale (*Mesoplodon stejnegeri)*	
	Strap-toothed beaked whale (*Mesoplodon layardii)*	
	True's beaked whale (*Mesoplodon mirus)*	
Monodontidae	Beluga (*Delphinapterus leucas*)	Endangered (Only Cook Inlet stock)

Table 4. Marine mammal species potentially occurring in SURTASS LFA sonar operating areas and their status under the Endangered Species Act (ESA).

FAMILY	SPECIES	ESA STATUS
Delphinidae	Killer whale (*Orca orcinus*)	Endangered (Only Southern Resident population)
	False killer whale (*Pseudorca crassidens*)	
	Pygmy killer whale (*Feresa attenuata*)	
	Melon-headed whale (*Peponocephala electra*)	
	Long-finned pilot whale (*Globicephala melas*)	
	Short-finned pilot whale (*Globicephala macrorhynchus)*	
	Risso's dolphin (*Grampus griseus*)	
	Short-beaked common dolphin (*Delphinus delphis*)	
	Long-beaked common dolphin (*Delphinus capensis)*	
	Fraser's dolphin (*Lagenodelphis hosei*)	
	Common bottlenose dolphin (*Tursiops truncatus*)	
	Indo-Pacific bottlenose dolphin (*Tursiops aduncus*)	
	Pantropical spotted dolphin (*Stenella attenuata*)	
	Striped dolphin (*Stenella coeruleoalba)*	
	Atlantic spotted dolphin (*Stenella frontalis)*	
	Spinner dolphin (*Stenella longirostris)*	
	Clymene dolphin (*Stenella clymene)*	
	Peale's dolphin (*Lagenorhynchus australis*)	
	Dusky dolphin (*Lagenorhynchus obscurus)*	
	Atlantic white-sided dolphin (*Lagenorhynchus acutus)*	
	White-beaked dolphin (*Lagenorhynchus albirostris)*	
	Hourglass dolphin (*Lagenorhynchus cruciger)*	
	Pacific white-sided dolphin (*Lagenorhynchus obliquidens)*	
	Rough-toothed dolphin (*Steno bredanensis*)	
	Northern right whale dolphin (*Lissodelphis borealis*)	
	Southern right whale dolphin (*Lissodelphis peronii)*	
	Commerson's dolphin (*Cephalorhynchus commersonii*)	
	Chilean dolphin (*Cephalorhynchus eutropia)*	
	Heaviside's dolphin (*Cephalorhynchus heavisidii)*	
	Hector's dolphin (*Cephalorhynchus hectori)*	
Phocoenidae	Dall's porpoise (*Phocoenoides dalli*)	
	Harbor porpoise (*Phocoena phocoena*)	
	Spectacled porpoise (*Phocoena dioptrica)*	
Pinnipeds		
Otariidae	South American fur seal (*Arctocephalus australis*)	
	New Zealand fur seal (*Arctocephalus forsteri)*	
	Galapagos fur seal (*Arctocephalus galapagoensis)*	
	Juan Fernadez fur seal (*Arctocephalus philippi)*	

Table 4. Marine mammal species potentially occurring in SURTASS LFA sonar operating areas and their status under the Endangered Species Act (ESA).

FAMILY	SPECIES	ESA STATUS
	South African and Australian fur seals (*Arctocephalus pusillus)*	
	Guadalupe fur seal (*Arctocephalus townsendi)*	Threatened (foreign)
	Subantarctic fur seal (*Arctocephalus tropicalis)*	
	Northern fur seal (*Callorhinus ursinus*)	
	Steller sea lion (*Eumetopias jubatus*)	Endangered (Western DPS); Threatened (Eastern DPS)
	California sea lion (*Zalophus californianus*)	
	Galapagos sea lion (*Zalophus wollebaeki)*	
	Australian sea lion (*Neophoca cinerea*)	
	New Zealand fur seal (*Phocarctos hookeri*)	
	South American sea lion (*Otaria flavescens*)	
Phocidae	Mediterranean monk seal (*Monachus monachus)*	Endangered (foreign)
	Hawaiian monk seal (*Monachus schauinslandi*)	Endangered
	Northern elephant seal (*Mirounga angustirostris)*	
	Southern elephant seal (*Mirounga leonina)*	
	Ribbon seal (*Phoca fasciata)*	
	Spotted seal (*Phoca largha*)	Threatened (Southern DPS)
	Harbor seal (*Phoca vitulina*)	
	Gray seal *(Halichoerus grypus)*	
	Hooded seal (*Cystophora cristata*)	
	Harp seal (*Pagophilus groenlandicus*)	

and analysis and were not always available for each species/stocks in all operating areas. When density estimates were not available from a survey in the operating area, then density estimates from a region with similar oceanographic characteristics were extrapolated to that operating area. For example, the eastern tropical Pacific has been extensively surveyed and provides a comprehensive understanding of marine mammals in temperate oceanic waters (Ferguson and Barlow, 2001, 2003). Further, density estimates are sometimes pooled for species of the same genus if sufficient data are not available to compute a density for individual species or the species are difficult to distinguish at sea. This is often the case for pilot whales and beaked whales, as well as the pygmy and dwarf sperm whales. Density estimates are available for these species groups rather than the individual species.

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density Reference(s)[8]
Site 1: East of Japan					
Blue whale	NP	9,250	1, 2, 3	0.0002	1, 2, 3
Fin whale	NP	9,250	1, 2, 3	0.0002	1, 2, 3
Sei whale	NP	8,600	1	0.0006	1, 2
Bryde's whale	WNP	20,501	4	0.0006	3
Minke whale	WNP "O" Stock	25,049	5	0.0022	5
North Pacific right whale (spring, fall)	WNP	922	6	<0.00001	
Sperm whale	NP	102,112	7	0.0010	8
Kogia spp.	NP	350,553	9, 10	0.0031	9, 10
Baird's beaked whale	WNP	8,000	11	0.0029	11
Cuvier's beaked whale	NP	90,725	10	0.0054	10
Ginkgo-toothed beaked whale	NP	22,799	9, 10	0.0005	9, 10
Hubbs' beaked whale	NP	22,799	9, 10	0.0005	9, 10
False killer whale (pelagic stock)	WNP	16,668	12	0.0036	12
Pygmy killer whale	WNP	30,214	10	0.0021	10
Short-finned pilot whale	WNP	53,608	12	0.0128	12
Risso's dolphin	WNP	83,289	12	0.0097	12
Common dolphin	WNP	3,286,163	9, 10	0.0761	9, 10
Fraser's dolphin	WNP	220,789	9, 10	0.0040	9, 10
Bottlenose dolphin	WNP	168,791	12	0.0171	12

7 NP=North Pacific; WNP=Western North Pacific; ENP=Eastern North Pacific; CNP=Central North Pacific; IA=Inshore Archipelago; SOJ=Sea of Japan; ECS=East China Sea; CA/OR/WA=California, Oregon, and Washington; WNA=Western North Atlantic; ENA=Eastern North Atlantic; MED=Mediterranean; WMED=Western Mediterranean; IND=Indian Ocean; XAR=Stock X/Arabian Sea; ETP=Eastern Tropical Pacific; NEOP=Northeastern Offshore Pacific; WSP=Western South Pacific; GVEA=Group V East Australia

8 Literature references associated with the numerical values listed in table are found at the end of the table.

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density Reference(s)[8]
Pantropical spotted dolphin	WNP	438,064	12	0.0259	12
Striped dolphin	WNP	570,038	12	0.0111	12
Spinner dolphin	WNP	1,015,059	9, 10	0.0005	9, 10
Pacific white-sided dolphin	WNP	931,000	9, 10	0.0082	9, 10
Rough-toothed dolphin	WNP	145,729	9, 10	0.0059	9, 10
Site 2: North Philippine Sea					
Bryde's whale	WNP	20,501	4	0.0006	3
Minke whale	WNP “O” Stock	25,049	5	0.0044	5
North Pacific right whale (fall to spring)	WNP	922	6	<0.00001	
Sperm whale	NP	102,112	14	0.0028	15
Kogia spp.	NP	350,553	9, 10	0.0031	9, 10
Cuvier's beaked whale	NP	90,725	10	0.0054	10
Blainville's beaked whale	NP	8,032	9, 10	0.0005	9, 10
Ginkgo-toothed beaked whale	NP	22,799	9, 10	0.0005	9, 10
Killer whale	NP	12,256	9, 10	0.0004	9, 10
False killer whale (pelagic stock)	WNP	16,668	12	0.0029	12
Pygmy killer whale	WNP	30,214	10	0.0021	10
Melon-headed whale	WNP	36,770	9, 10	0.0012	15
Short-finned pilot whale	WNP	53,608	12	0.0153	12
Risso's dolphin	WNP	83,289	12	0.0106	12
Common dolphin	WNP	3,286,163	9, 10	0.0562	9, 10
Fraser’s dolphin	WNP	220,789	9, 10	0.0040	9, 10
Bottlenose dolphin	WNP	168,791	12	0.0146	12
Pantropical spotted dolphin	WNP	438,064	12	0.0137	12
Striped dolphin	WNP	570,038	12	0.0329	12

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density reference(s)[8]
Spinner dolphin	WNP	1,015,059	9, 10	0.0005	9, 10
Pacific white-sided dolphin	WNP	931,000	9, 10	0.0119	9, 10
Rough-toothed dolphin	WNP	145,729	9, 10	0.0059	9, 10
Site 3: West Philippine Sea					
Fin whale	NP	9,250	2, 3, 4	0.0002	2, 3, 4
Bryde's whale	WNP	20,501	4	0.0006	3
Minke whale	WNP “O” Stock	25,049	5	0.0033	5
Humpback whale (winter only)	WNP	1,107	16	0.0008	17
Sperm whale	NP	102,112	7	0.0010	8
Kogia spp.	NP	350,553	9	0.0017	10
Cuvier's beaked whale	NP	90,725	10	0.0003	10
Blainville's beaked whale	NP	8,032	9, 10	0.0005	9, 10
Ginkgo-toothed beaked whale	NP	22,799	9, 10	0.0005	9, 10
False killer whale (pelagic stock)	WNP	16,668	12	0.0029	12
Pygmy killer whale	WNP	30,214	10	0.0021	10
Melon-headed whale	WNP	36,770	9, 10	0.0012	15
Short-finned pilot whale	WNP	53,608	12	0.0076	12
Risso's dolphin	WNP	83,289	12	0.0106	12
Common dolphin	WNP	3,286,163	9, 10	0.0562	9, 10
Fraser's dolphin	WNP	220,789	9, 10	0.0040	9, 10
Bottlenose dolphin	WNP	168,791	12	0.0146	12
Pantropical spotted dolphin	WNP	438,064	12	0.0137	12
Striped dolphin	WNP	570,038	12	0.0164	12
Spinner dolphin	WNP	1,015,059	9, 10	0.0005	9, 10
Pacific white-sided dolphin	WNP	931,000	9, 10	0.0245	9, 10

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

MARINE MAMMAL SPECIES NAME	STOCK NAME[7]	STOCK / ABUNDANCE (ANIMALS)	STOCK / ABUNDANCE REFERENCE(S)[8]	DENSITY (ANIMALS PER KM^2)	DENSITY REFERENCE(S)[8]
Rough-toothed dolphin	WNP	145,729	9, 10	0.0059	9, 10
SITE 4: OFFSHORE GUAM					
Blue whale	ENP	2,842	18	0.0001	9, 10
Fin whale	ENP	9,250	10	0.0003	10
Sei whale	NP	8,600	1	0.0003	19
Bryde's whale	WNP	20,501	4	0.0004	19
Minke whale	WNP “O” Stock	25,049	5	0.0003	9, 10
Humpback whale (October to May only)	CNP	10,103	16	0.0069	9, 10
Sperm whale	NP	102,112	7	0.0012	19
Kogia spp.	NP	350,553	10	0.0101	15
Cuvier's beaked whale	NP	90,725	10	0.0062	15
Blainville's beaked whale	NP	8,032	10	0.0012	15
Ginkgo-toothed beaked whale	NP	22,799	9, 10	0.0005	9, 10
Longman’s beaked whale	CNP	1,007	15	0.0004	15
Killer whale	CNP	349	15	0.0001	15
False killer whale (pelagic stock)	WNP	16,668	12	0.0011	19
Pygmy killer whale	WNP	30,214	10	0.0001	19
Melon-headed whale	WNP	36,770	10	0.0043	19
Short-finned pilot whale	WNP	53,608	12	0.0016	19
Risso's dolphin	WNP	83289	12	0.0010	15
Common dolphin	WNP	3,286,163	9, 10	0.0021	9, 10
Fraser’s dolphin	CNP	10,226	15	0.0042	15
Bottlenose dolphin	WNP	168,791	12	0.0002	19
Pantropical spotted dolphin	WNP	438,064	12	0.0226	19
Striped dolphin	WNP	570,038	12	0.0062	19

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density reference(s)[8]
Spinner dolphin	WNP	1,015,059	10	0.0031	19
Rough-toothed dolphin	WNP	145,729	10	0.0003	19
Site 5: Sea of Japan					
Fin whale	NP	9,250	1, 2, 3	0.0009	9, 10
Bryde's whale	WNP	20,501	4	0.0001	10
Minke whale	WNP “O” Stock	25,049	5	0.0004	10
Minke whale	WNP “J” Stock	893	20	0.0002	20
North Pacific right whale (fall to spring)	WNP	922	6	<0.00001	
Gray whale	WNP	121	4	<0.00001	
Sperm whale	NP	102,112	7	0.0008	10
Stejneger's beaked whale	NP	8,000	11	0.0014	10
Baird's beaked whale	WNP	8,000	11	0.0003	9, 10
Cuvier's beaked whale	NP	90,725	10	0.0043	10
Ginkgo-toothed beaked whale	NP	22,799	9, 10	0.0005	9, 10
False killer whale (pelagic stock)	IA	9,777	12	0.0027	10
Melon-headed whale	WNP	36,770	10	0.00001	10
Short-finned pilot whale	WNP	53,608	12	0.0014	12
Risso's dolphin	WNP	83,289	12	0.0073	12
Common dolphin	WNP	3,286,163	9, 10	0.0860	9, 10
Bottlenose dolphin	IA	105,138	21	0.0009	10
Pantropical spotted dolphin	WNP	219,032	12	0.0137	12
Spinner dolphin	WNP	1,015,059	9, 10	0.00001	9, 10
Pacific white-sided dolphin	WNP	931,000	9, 10	0.0030	9, 10
Dall's porpoise	SOJ	76,720	10	0.0520	10

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density Reference(s)[8]
Site 6: East China Sea					
Fin whale	ECS	500	1, 2, 3	0.0002	1, 2, 3
Bryde's whale	WNP	20,501	4	0.0006	3
Minke whale	WNP "O" Stock	25,049	5	0.0044	5
Minke whale	WNP "J" Stock	893	20	0.0018	20
North Pacific right whale (winter only)	WNP	922	6	<0.00001	
Gray whale (winter only)	WNP	121	4	<0.00001	
Sperm whale	NP	102,112	7	0.0012	19
Kogia spp.	NP	350,553	9	0.0031	10
Cuvier's beaked whale	NP	90,725	10	0.0062	15
Blainville's beaked whale	NP	8,032	9, 10	0.0012	9, 10
Ginkgo-toothed beaked whale	NP	22,799	9, 10	0.0005	9, 10
False killer whale (pelagic stock)	IA	9,777	21	0.0011	19
Pygmy killer whale	WNP	30,214	10	0.0001	19
Melon-headed whale	WNP	36,770	10	0.0043	19
Short-finned pilot whale	WNP	53,608	12	0.0016	19
Risso's dolphin	WNP	83,289	12	0.0106	12
Common dolphin	WNP	3,286,163	9, 10	0.0461	9, 10
Fraser's dolphin	WNP	220,789	9, 10	0.0040	9, 10
Bottlenose dolphin	IA	105,138	21	0.0146	12
Pantropical spotted dolphin	WNP	219,032	12	0.0137	12
Striped dolphin	WNP	570,038	12	0.0164	12
Spinner dolphin	WNP	1,015,059	10	0.0031	19
Pacific white-sided dolphin	WNP	931,000	9, 10	0.0028	9, 10
Rough-toothed dolphin	WNP	145,729	10	0.0059	9, 10

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density Reference(s)[8]
Site 7: South China Sea					
Fin whale	WNP	9,250	1, 2, 3	0.0002	1, 2, 3
Bryde's whale	WNP	20,501	4	0.0006	3
Minke whale	WNP “O” Stock	25,049	5	0.0033	5
North Pacific right whale (winter only)	WNP	922	6	<0.00001	
Gray whale (winter only)	WNP	121	4	<0.0001	
Sperm whale	NP	102,112	7	0.0012	19
Kogia spp.	NP	350,553	9	0.0017	10
Cuvier's beaked whale	NP	90,725	10	0.0003	10
Blainville's beaked whale	NP	8,032	9, 10	0.0005	9, 10
Ginkgo-toothed beaked whale	NP	22,799	9, 10	0.0005	9, 10
False killer whale (pelagic stock)	IA	9,777	21	0.0011	19
Pygmy killer whale	WNP	30,214	10	0.0001	19
Melon-headed whale	WNP	36,770	10	0.0043	19
Short-finned pilot whale	WNP	53,608	12	0.0016	19
Risso's dolphin	WNP	83,289	12	0.0106	12
Common dolphin	WNP	3,286,163	9, 10	0.0461	9, 10
Fraser's dolphin	WNP	220,789	9, 10	0.0040	9, 10
Bottlenose dolphin	IA	105,138	21	0.0146	12
Pantropical spotted dolphin	WNP	219,032	12	0.0137	12
Striped dolphin	WNP	570,038	12	0.0164	12
Spinner dolphin	WNP	1,015,059	10	0.3140	19
Rough-toothed dolphin	WNP	145,729	9, 10	0.0040	9, 10
Site 8: Offshore Japan (25º to 40ºN)					
Blue whale	NP	9,250	1	0.0003	1

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density reference(s)[8]
Fin whale	NP	9,250	1, 2, 3	0.0001	1, 2, 3
Sei whale	NP	37,000	3	0.0003	19
Bryde's whale	WNP	20,501	4	0.0004	19
Minke whale	WNP "O" Stock	25,049	5	0.0003	5
Sperm whale	NP	102,112	7	0.0003	9, 10
Kogia spp.	NP	350,553	9	0.0049	10
Baird's beaked whale	WNP	8,000	11	0.0001	11
Cuvier's beaked whale	NP	90,725	10	0.0017	10
Mesoplodon spp.	NP	22,799	9, 10	0.0005	9, 10
False killer whale (pelagic stock)	WNP	16,668	12	0.0036	12
Pygmy killer whale	WNP	30,214	10	0.0001	19
Melon-headed whale	WNP	36,770	10	0.0012	15
Short-finned pilot whale	WNP	53,608	12	0.0001	10
Risso's dolphin	WNP	83,289	12	0.0010	10
Common dolphin	WNP	3,286,163	9, 10	0.0863	9, 10
Bottlenose dolphin	WNP	168,791	12	0.0005	10
Pantropical spotted dolphin	WNP	438,064	12	0.0181	9, 10
Striped dolphin	WNP	570,038	12	0.0500	9, 10
Spinner dolphin	WNP	1,015,059	9, 10	0.00001	9, 10
Pacific white-sided dolphin	WNP	67,769	9, 10	0.0048	9, 10
Rough-toothed dolphin	WNP	145,729	9, 10	0.0003	19
Hawaiian monk seal	Hawaii	1,129	18	<0.00001	
Site 9: Offshore Japan (10° to 25°N)					
Bryde's whale	WNP	20,501	4	0.0004	19
Sperm whale	NP	102,112	22	0.0004	9, 10

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density reference(s)[8]
Kogia spp.	NP	350,553	9	0.0009	10
Cuvier's beaked whale	NP	90,725	10	0.0017	10
False killer whale (pelagic stock)	WNP	16,668	12	0.0021	12
Melon-headed whale	WNP	36,770	10	0.0012	15
Short-finned pilot whale	WNP	53,608	12	0.0009	10
Risso's dolphin	WNP	83,289	12	0.0026	10
Common dolphin	WNP	3,286,163	9, 10	0.0863	9, 10
Bottlenose dolphin	WNP	168,791	12	0.0007	10
Pantropical spotted dolphin	WNP	438,064	12	0.0226	19
Striped dolphin	WNP	570,038	12	0.0110	12
Spinner dolphin	WNP	1,015,059	10	0.0031	19
Rough-toothed dolphin	WNP	145,729	9, 10	0.0003	19
Site 10: Hawaii North					
Blue whale	WNP	1,548	17	0.0002	9, 10
Fin whale	Hawaii	2,099	17	0.0007	9, 10
Bryde’s whale	Hawaii	469	15	0.0002	15
Minke whale	WNP	25,000	5	0.0002	9, 10
Humpback whale (summer)	Hawaii	10,103	16	<0.0001	15
Sperm whale	CNP	6,919	15	0.0028	15
Kogia spp	Hawaii	24,657	15	0.0101	15
Cuvier’s beaked whale	Hawaii	15,242	15	0.0062	15
Blainville’s beaked whale	Hawaii	2,872	15	0.0012	15
Longman’s beaked whale	Hawaii	1,007	15	0.0004	15
Killer whale	Hawaii	349	15	0.0001	15
False killer whale	Hawaii Pelagic	484	61	0.0002	61

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density Reference(s)[8]
Pygmy killer whale	Hawaii	956	15	0.0004	15
Melon-headed whale	Hawaii	2,950	15	0.0012	15
Short-finned pilot whale	Hawaii	8,870	15	0.0036	15
Risso's dolphin	Hawaii	2,372	15	0.0010	15
Fraser's dolphin	Hawaii	10,226	15	0.0042	15
Bottlenose dolphin	Hawaii	3,215	15	0.0013	15
Pantropical spotted dolphin	Hawaii	8,978	15	0.0037	15
Striped dolphin	Hawaii	13,143	15	0.0054	15
Spinner dolphin	Hawaii	3,351	15	0.0014	15
Rough-toothed dolphin	Hawaii	8,709	15	0.0036	15
Hawaiian monk seal	Hawaii	1,129	18	<0.0001	
Site 11: Hawaii South					
Blue whale	WNP	1,548	17	0.0002	9, 10
Fin whale	Hawaii	2,099	17	0.0007	9, 10
Bryde's whale	Hawaii	469	15	0.0002	15
Minke whale	Hawaii	25,000	5	0.0002	9, 10
Humpback whale (fall through spring)	Hawaii	10,103	16	0.0008	17
Sperm whale	CNP	6,919	15	0.0028	15
Kogia spp.	Hawaii	24,657	15	0.0101	15
Cuvier's beaked whale	Hawaii	15,242	15	0.0062	15
Blainville's beaked whale	Hawaii	2,872	15	0.0012	15
Longman's beaked whale	Hawaii	1,007	15	0.0004	15
Killer whale	Hawaii	349	15	0.0001	15
False killer whale	Hawaii Pelagic	484	61	0.0002	61
Pygmy killer whale	Hawaii	956	15	0.0004	15

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density Reference(s)[8]
Melon-headed whale	Hawaii	2,950	15	0.0012	15
Short-finned pilot whale	Hawaii	8,870	15	0.0036	15
Risso's dolphin	Hawaii	2,372	15	0.0010	15
Fraser's dolphin	Hawaii	10,226	15	0.0042	15
Bottlenose dolphin	Hawaii	3,215	15	0.0013	15
Pantropical spotted dolphin	Hawaii	8,978	15	0.0037	15
Striped dolphin	Hawaii	13,143	15	0.0054	15
Spinner dolphin	Hawaii	3,351	15	0.0014	15
Rough-toothed dolphin	Hawaii	8,709	15	0.0036	15
Hawaiian monk seal	Hawaii	1,129	18	<0.0001	
Site 12: Offshore Southern California (in SOCAL OPAREA)					
Blue whale	ENP	2,842	18	0.0014	17
Fin whale	CA/OR/WA	2,099	17	0.0018	17
Sei whale	ENP	98	17	0.0001	17
Bryde's whale	ENP	13,000	24	0.00001	24
Northern minke whale	CA/OR/WA	823	17	0.0007	17
Humpback whale	CA/OR/WA	942	17	0.0008	17
Gray whale	ENP	18,813	14	0.051	25
Sperm whale	CA/OR/WA	1,934	17	0.0017	17
Pygmy sperm whale	CA/OR/WA	1,237	17	0.0011	17
Stejneger's beaked whale	CA/OR/WA	1,177	17	0.0010	17
Baird's beaked whale	CA/OR/WA	1,005	17	0.0009	17
Cuvier's beaked whale	CA/OR/WA	4,342	17	0.0038	17
Blainville's beaked whale	CA/OR/WA	1,177	17	0.0010	17
Ginkgo-toothed beaked whale	CA/OR/WA	1,177	17	0.0010	17

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density Reference(s)[8]
Hubb's beaked whale	CA/OR/WA	1,177	17	0.0010	17
Longman's beaked whale	Hawaii	1,177	17	0.0010	17
Perrin's beaked whale	CA/OR/WA	1,177	17	0.0010	17
Pygmy beaked whale	CA/OR/WA	1,177	17	0.0010	17
Killer whale	ENP Offshore	810	17	0.0007	17
Short-finned pilot whale	CA/OR/WA	350	17	0.0003	17
Risso's dolphin	CA/OR/WA	11,910	17	0.0105	17
Long-beaked common dolphin	CA/OR/WA	21,902	17	0.0192	17
Short-beaked common dolphin	CA/OR/WA	352,069	17	0.3094	17
Bottlenose dolphin	CA/OR/WA offshore	2,026	17	0.0018	17
Striped dolphin	CA/OR/WA	18,976	17	0.0167	17
Pacific white-sided dolphin	CA/OR/WA	23,817	17	0.0209	17
Northern right whale dolphin	CA/OR/WA	11,097	17	0.0098	17
Dall's porpoise	CA/OR/WA	85,955	17	0.0753	17
Guadalupe fur seal	Mexico	7,408	18	0.007	25
Northern fur seal	San Miguel Island	9,424	18	0	25
California sea lion (on shelf)	California	238,000	18	0.54	25
California sea lion (offshore)	California	238,000	18	0	25
Harbor seal	California	34,233	18	0.0095	25
Northern elephant seal (on shelf)	California Breeding	124,000	18	0.0045	25
Northern elephant seal (offshore)	California Breeding	124,000	18	0	25

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density reference(s)[8]
Site 13: Northwestern Atlantic off Florida (in JAX OPAREA)					
Humpback whale	WNA	11,570	27	0.0006	26
North Atlantic right whale (on shelf; winter to spring only)	WNA	438	28	0.0012	26
Sperm whale (on shelf)	WNA	4,804	29	0	26
Sperm whale (off shelf)	WNA	4,804	29	0.0005	26
Kogia spp.	WNA	580	30	0.0010	26
Beaked whales (on shelf)	WNA	3,513	29	0	26
Beaked whales (off shelf)	WNA	3,513	29	0.0006	26
Cuvier's beaked whale	WNA	3,513	29	0.0006	26
Blainville's beaked whale	WNA	3,513	29	0.0006	26
Gervais' beaked whale	WNA	3,513	29	0.0006	26
Sowerby's beaked whale	WNA	3,513	29	0.0006	26
True's beaked whale	WNA	3,513	29	0.0006	26
Short-finned pilot whale (on shelf)	WNA	31,139	29	0.00004	26
Short-finned pilot whale (off shelf)	WNA	31,139	29	0.0271	26
Risso's dolphin (on shelf)	WNA	20,479	29	0.0009	26
Risso's dolphin (off shelf)	WNA	20,479	29	0.0181	26
Common dolphin	WNA	120,743	29	0.00002	26
Bottlenose dolphin (on shelf)	WNA	81,588	29	0.2132	26
Bottlenose dolphin (off shelf)	WNA	81,588	29	0.1163	26
Pantropical spotted dolphin	WNA	12,747	30	0.0223	26
Striped dolphin	WNA	94,462	29	0.00003	26
Atlantic spotted dolphin (on shelf)	WNA	50,978	29	0.4435	26
Atlantic spotted dolphin (off shelf)	WNA	50,978	29	0.0041	26
Clymene dolphin	WNA	6,086	29	0.0106	26

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density Reference(s)[8]
Rough-toothed dolphin	WNA	274	30	0.0005	26
Site 14: Northeastern Atlantic off United Kingdom					
Blue whale	ENA	100	31, 32	0.00001	32
Fin whale	ENA	10,369	32	0.0031	32
Sei whale	ENA	14,152	33, 34	0.0113	33
Northern minke whale	ENA	107,205	35	0.0068	36
Humpback whale	ENA	4,695	32	0.0019	32
Sperm whale	ENA	6,375	32	0.0049	32
Kogia spp.	ENA	580	30	0.0001	30
Cuvier's beaked whale	ENA	3,513	29	0.0013	26
Blainville's beaked whale	ENA	3,513	29	0.0013	26
Sowerby's beaked whale	ENA	3,513	29	0.0013	26
Northern bottlenose whale	ENA	5,827	38	0.0003	37
Killer whale	ENA	6,618	38	0.0001	37
False killer whale (pelagic)	ENA	484	18	0.0001	37
Long-finned pilot whale	ENA	778,000	39	0.0121	26
Risso's dolphin	ENA	20,479	29	0.0063	26
Common dolphin	ENA	273,150	40	0.238	31
Bottlenose dolphin	ENA	81,588	29	0.0094	26
Striped dolphin	ENA	94,462	29	0.0765	26
Atlantic white-sided dolphin	ENA	11,760	36	0.0027	36
White-beaked dolphin	ENA	11,760	36	0.0027	36
Harbor porpoise	ENA	341,366	36	0.2299	36
Harbor seal	Ireland / Scotland	23,500	41	0.0230	26
Gray seal	ENA	113,300	42	0.027	26

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density reference(s)[8]
Site 15: Western Mediterranean Sea—Ligurian Sea					
Fin whale	MED	3,583	44	0.004	43, 44, 45
Sperm whale	WMED	6,375	32	0.0049	32
Cuvier's beaked whale	ENA	3,513	29	0.0013	26
Long-finned pilot whale	ENA	778,000	39	0.0121	26
Risso's dolphin	WMED	5,320	46, 47	0.0075	46
Common dolphin	WMED	19,428	48	0.0144	48
Bottlenose dolphin	WMED	23,304	46, 49, 50	0.041	46
Striped dolphin	WMED	117,880	51	0.24	51
Site 16: Northern Arabian Sea					
Bryde's whale	IND	9,176	24	0.0001	52, 53
Humpback whale	XAR	200	54, 55, 56	0.0004	9, 10
Sperm whale	IND	24,446	24	0.0125	52, 53
Dwarf sperm whale	IND	10,541	24	0.0145	52, 53
Cuvier's beaked whale	IND	27,272	24	0.0001	52, 53
Blainville's beaked whale	IND	16,867	24	0.0016	52, 53
Gingko-toothed beaked whale	IND	16,867	24	0.0016	52, 53
Longman's beaked whale	IND	16,867	24	0.0016	52, 53
False killer whale (pelagic)	IND	144,188	24	0.0003	52, 53
Pygmy killer whale	IND	22,029	24	0.0026	52, 53
Melon-headed whale	IND	64,600	24	0.0661	52, 53
Short-finned pilot whale	IND	268,751	24	0.0034	52, 53
Risso's dolphin	IND	452,125	24	0.0125	52, 53
Common dolphin	IND	1,819,882	24	0.0265	52, 53
Bottlenose dolphin	IND	785,585	24	0.0164	52, 53

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density Reference(s)[8]
Pantropical spotted dolphin	IND	736,575	24	0.0127	52, 53
Striped dolphin	IND	674,578	24	0.0706	52, 53
Spinner dolphin	IND	634,108	24	0.01	52, 53
Rough-toothed dolphin	IND	156,690	24	0.0081	52, 53
Site 17: Andaman Sea (off Myanmar)					
Bryde's whale	IND	9,176	24	0.0001	52, 53
Sperm whale	IND	24,446	24	0.0125	52, 53
Dwarf sperm whale	IND	10,541	24	0.0145	52, 53
Cuvier's beaked whale	IND	27,272	24	0.0001	52, 53
Blainville's beaked whale	IND	16,867	24	0.0016	52, 53
Gingko-toothed beaked whale	IND	16,867	24	0.0016	52, 53
Longman's beaked whale	IND	16,867	24	0.0016	52, 53
Killer whale	IND	12,593	24	0.0001	52, 53
False killer whale (pelagic)	IND	144,188	24	0.0003	52, 53
Pygmy killer whale	IND	22,029	24	0.0026	52, 53
Melon-headed whale	IND	64,600	24	0.0661	52, 53
Short-finned pilot whale	IND	268,751	24	0.0034	52, 53
Risso's dolphin	IND	452,125	24	0.0125	52, 53
Common dolphin	IND	1,819,882	24	0.0265	52, 53
Bottlenose dolphin	IND	785,585	24	0.0164	52, 53
Pantropical spotted dolphin	IND	736,575	24	0.0127	52, 53
Striped dolphin	IND	674,578	24	0.0706	52, 53
Spinner dolphin	IND	634,108	24	0.01	52, 53
Rough-toothed dolphin	IND	156,690	24	0.0081	52, 53

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density Reference(s)[8]
Site 18: Panama Canal—West Approach					
Blue whale	ENP	2,842	18	0.0001	9, 10
Bryde's whale	ETP	13,000	24	0.0003	9, 10
Humpback whale	ENP	1,391	18	0.0004	9, 10
Sperm whale	ETP	22,700	24	0.0047	9, 10
Dwarf sperm whale	ETP	11,200	24	0.0145	9, 10
Cuvier's beaked whale	ETP	20,000	24	0.0025	9, 10
Blainville's beaked whale	ETP	25,300	24	0.0013	9, 10
Gingko-toothed beaked whale	ETP	25,300	24	0.0016	9, 10
Longman's beaked whale	ETP	25,300	24	0.0003	9, 10
Pygmy beaked whale	ETP	25,300	24	0.0016	9, 10
Killer whale	ETP	8,500	24	0.0002	9, 10
False killer whale (pelagic)	ETP	39,800	24	0.0004	9, 10
Pygmy killer whale	ETP	38,900	24	0.0014	9, 10
Melon-headed whale	ETP	45,400	24	0.0174	9, 10
Short-finned pilot whale	ETP	160,200	24	0.0058	9, 10
Risso's dolphin	ETP	110,457	57	0.0161	9, 10
Common dolphin	ETP	3,127,203	57	0.049	9, 10
Fraser's dolphin	ETP	289,300	24	0.001	9, 10
Bottlenose dolphin	ETP	335,834	57	0.0157	9, 10
Pantropical spotted dolphin	NEOP	640,000	58	0.0669	9, 10
Striped dolphin	ETP	964,362	57	0.1199	9, 10
Spinner dolphin	Eastern	450,000	58	0.007	9, 10
Rough-toothed dolphin	ETP	107,633	57	0.0146	9, 10

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density Reference(s)[8]
Site 19: Northeastern Australia Coast					
Blue whale	WSP	9,250	1, 2, 3	0.0002	1, 2, 3
Fin whale	WSP	9,250	1, 2, 3	0.0002	1, 2, 3
Bryde's whale	WSP	22,000	4	0.0006	3
Northern minke whale	WSP	25,000	5	0.0044	5
Humpback whale	GVEA	3,500	59	0.0143	59
Sperm whale	WSP	102,112	14	0.0029	14
Kogia spp.	WSP	350,553	9, 10	0.0031	9, 10
Cuvier's beaked whale	WSP	90,725	10	0.0054	10
Blainville's beaked whale	WSP	8,032	9, 10	0.0005	9, 10
Amoux's beaked whale	WSP	22,799	9, 10	0.0005	9, 10
Gingko-toothed beaked whale	WSP	22,799	9, 10	0.0005	9, 10
Longman's beaked whale	WSP	22,799	9, 10	0.0005	9, 10
Southern bottlenose whale	WSP	22,799	9, 10	0.0005	9, 10
Killer whale	WSP	12,256	9, 10	0.0004	9, 10
False killer whale (pelagic)	WSP	16,668	12	0.0029	12
Pygmy killer whale	WSP	30,214	10	0.0021	10
Melon-headed whale	WSP	36,770	9, 10	0.0012	15
Globicephala spp.	WSP	53,608	12	0.0153	12
Risso's dolphin	WSP	83,289	12	0.0106	12
Common dolphin	WSP	3,286,163	9, 10	0.0562	9, 10
Fraser's dolphin	WSP	220,789	9, 10	0.004	9, 10
Bottlenose dolphin	WSP	168,791	12	0.0146	12
Pantropical spotted dolphin	WSP	438,064	12	0.0137	12
Striped dolphin	WSP	570,038	12	0.0329	12

Table 5. Abundance estimates, density estimates, as well as associated references for the marine mammal species, species groups, and stocks associated with each of the 19 analyzed SURTASS LFA sonar operating areas.

Marine Mammal Species Name	Stock Name[7]	Stock / Abundance (animals)	Stock / Abundance Reference(s)[8]	Density (animals per km^2)	Density reference(s)[8]
Spinner dolphin	WSP	1,015,059	9, 10	0.0005	9, 10
Dusky dolphin	WSP	12,626	60	0.0002	9, 10
Rough-toothed dolphin	WSP	145,729	9, 10	0.0059	9, 10

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9 Full citations for the literature listed here may be found in the Literature Cited section.

4 STATUS AND DISTRIBUTION OF POTENTIALLY AFFECTED MARINE MAMMAL SPECIES AND STOCKS

Requirement 4: Description of the status, distribution, and seasonal distribution of the affected species or stocks of marine mammals likely to be affected by such activities.

The status, distribution, stocks, abundance, diving behavior, life history, and hearing/vocalization for each of the marine mammal species potentially found in areas of the world's oceans where SURTASS LFA sonar may be operated is the focus of this chapter. The status of marine mammal populations is impacted by their biological characteristics, natural phenomenon, and interaction with anthropogenic activity. Many cetacean and pinniped populations have been reduced due to the exploitation of commercial whaling and harvesting, incidental fisheries bycatch, harmful algal blooms, and habitat destruction over the last centuries. The reduction in some marine mammal populations has led to the risk of extinction. The ESA, along with the international organizations such as the International Union of Conservation of Nature (IUCN), designate a protected status when species are at risk of extinction, generally based on natural or manmade factors affecting the continued existence of species. In addition, under the MMPA, species or stocks that are not at the optimal sustainable population level may be listed as depleted.

The distribution of marine mammals is difficult to predict as these highly mobile animals are capable of traveling long distances. Many species of marine mammals move extensive distances between feeding grounds at high latitudes during warmer seasons and calving/breeding grounds in the lower latitudes during colder seasons. Even slow-moving cetaceans are capable of traveling nearly 200 km (108 nmi) within a 24-hour period. Some baleen whales, such as the humpback and North Atlantic right whales, make extensive annual migrations to low-latitude mating and calving grounds in the winter and to high-latitude feeding grounds in the spring and summer. At nearly 16,093 km (8,690 nmi) round trip, the migratory movements of the humpback whale represent the longest migration of any mammal (Clapham, 2002). Despite this mobility, however, the distribution of marine mammals is not typically random and is not homogeneous but is often characterized by irregular clusters (patches) of occurrence that frequently correlate with locations of high prey abundance. Marine mammals are often associated with features such as oceanographic fronts or regions of persistent upwelling because these areas of increased primary productivity attract marine mammal prey, such as squid and fishes.

The following sections include information on the status, stocks, abundance, distribution, diving behavior, and hearing/vocalization for each of the marine mammal species potentially found in areas of the world's oceans where SURTASS LFA sonar may be operated.

4.1 MYSTICETES

Mysticetes potentially affected by SURTASS LFA sonar include 12 species in four families (see Table 4). Mysticetes are characterized by paired blowholes and the large baleen plates used to capture zooplankton and small fishes. Due to decades of whaling, populations, many mysticete species and populations are imperiled throughout their worldwide ranges.

All mysticetes produce low frequency sounds, although no direct measurements of auditory (hearing) thresholds have been made for the majority of species as most tests for auditory measurements are impractical in such large animals (Clark, 1990; Richardson et al., 1995; Edds-Walton, 1997; Tyack, 2000; Evans and Raga, 2001). A few species' vocalizations are known to be communication signals but the function of other mysticete low-frequency sounds are not fully understood but likely are used for functions such as orientation, navigation, or detection of predators and prey. Several mysticete species, including the humpback, fin, bowhead, and blue whales, sing or emit repetitious patterned signals or vocalizations

(Frankel, 2009). Based on a study of the morphology of cetacean auditory mechanisms, Ketten (1994) hypothesized that mysticete hearing is in the low to infrasonic range. It is generally believed that baleen whales have frequencies of best hearing where their calls have the greatest energy—below 5,000 Hz (Ketten, 2000).

4.1.1 BLUE WHALE (*BALAENOPTERA MUSCULUS*)

The blue whale is currently listed as endangered under the ESA, depleted under the MMPA, protected under CITES, and as endangered (Antarctic), vulnerable (North Atlantic), and lower risk/conservation dependent (North Pacific) by the IUCN. The global population is estimated between 8,000 to 9,000 individuals (Jefferson et al., 2008), while 1,368 blue whales are estimated to occur in the eastern North Pacific (Carretta et al., 2009), 1,700 blue whales are estimated for the Southern Ocean (Branch et al., 2007), and 424 whales are estimated for the Madagascar Plateau region in the austral summer (Best, 2003). Stock structure of blue whales is not well defined, but the International Whaling Commission (IWC) has identified six southern hemisphere stocks, and based on vocalizations, two stocks of blue whales are thought to occur in the North Pacific (Jefferson et al., 2008; Sears and Perrin, 2009; Caretta et al., 2011). Two stocks are also indicated for the North Atlantic Ocean, based on photo-identifications (Waring et al., 2010).

Blue whales are distributed in subpolar to tropical continental shelf and deeper waters of all oceans and migrate between higher latitudes in summer and lower latitudes in winter (Jefferson et al., 2008; Sears and Perrin, 2009). Blue whales in the North Atlantic migrate as far north as Jan Mayen Island and Spitsbergen, Norway, in the summer but during the winter, they may migrate as far south as Florida or Bermuda (Jefferson et al., 2008). In the North Pacific, blue whales can be found as far north as the Gulf of Alaska but are mostly observed in California waters in the summer and Mexican and Central American waters in the winter (Jefferson et al., 2008; Sears and Perrin, 2009). Blue whales are also commonly found in the Southern Ocean (Jefferson et al., 2008).

Blue whales live for at least 80 to 90 years and reach sexual maturity between the ages of five to 15 years (Sears and Perrin, 2009). Females give birth every two to three years in winter. No breeding grounds are known in any ocean for blue whales, but mother-calf pairs are sighted routinely in the Gulf of California in late winter to spring, and it is likely that breeding grounds occur in subtropical to tropical waters (Jefferson et al., 2008; Sears and Perrin, 2009). Blue whales from the eastern North Pacific stock winter off Mexico, Central America, and as far south as 8º S (Stafford et al., 1999). The waters off California and Oregon represent an important feeding area in summer and fall for blue whales but, increasingly, whales from the eastern North Pacific stock have been observed feeding as far north as the Gulf of Alaska and as far south as Mexico and even the Costa Rica Dome region in summer to fall (Calambokidis et al., 2009; Munger et al., 2009). Most of this stock is believed to migrate south to spend the winter and spring in the high productivity waters off Baja California, the Gulf of California, and the Costa Rica Dome and blue whales can be assumed to feed year round (Caretta et al., 2011). Satellite tag data on blue whales in California waters show that individual whales often forage over extensive distances on a daily and weekly basis (Mate et al., 1999). Mate et al. (1999) used satellite tags to show that the eastern tropical Pacific is a migratory destination for blue whales that were tagged off southern California. Blue whales belonging to the central Pacific stock appear to feed in summer southwest of Kamchatka, south of the Aleutians, and in the Gulf of Alaska (Stafford, 2003; Watkins et al., 2000), while in winter they migrate to lower latitudes in the western Pacific and less frequently in the central Pacific, including Hawaii (Stafford et al., 2001). In the North Atlantic Ocean, blue whales observed in winter and spring around the Canary and Azores Islands are thought to perhaps be migrating northward along the mid-Atlantic Ridge to Iceland, where they are observed from May to September, while other blue whales in the eastern North Atlantic likely migrate along the European coast and far offshore to Iceland or Norway (Sears and Perrin, 2009). Where blue whales overwinter in the North Atlantic remains unclear. In the southern hemisphere, blue whales occur in the waters of the Madagascar Plateau in the austral summer, and recently, a feeding and nursery ground has been discovered off southern Chile (Hucke-Gaete et al., 2004).

The swimming and diving behavior of blue whales has been relatively well characterized. The average surface speed for a blue whale is 4.5 km/hr (2.4 kts) but can reach a maximum speed of 45 km/hr (18.9 kts) (Mate et al., 1999; Sears and Perrin, 2009). General dive times range from 4 to 15 min with average depths of 140 m (460 ft) (Croll et al., 2001a; Sears and Perrin, 2009). The longest dive recorded was 36 min (Sears and Perrin, 2009).

There is no direct measurement of the hearing sensitivity of blue whales (Ketten, 2000; Thewissen, 2002). In one of the few studies to date, no change in blue whale vocalization pattern or movements relative to an LFA sound source was observed for RLs of 70 to 85 dB (Aburto et al., 1997). Croll et al. (2001b) studied the effects of anthropogenic low-frequency noise on the foraging ecology of blue and fin whales off San Nicolas Island, California and observed no responses or change in foraging behavior that could be attributed to the low-frequency sounds.

Blue whales produce a variety of LF vocalizations ranging from 10 to 200 Hz (Edds, 1982; Thompson and Friedl, 1982; Alling and Payne, 1990; Clark and Fristrup, 1997; Rivers, 1997; Stafford et al., 1998, 1999a, 1999b, 2001; Frankel, 2009). These low frequency calls may be used as communicative signals (McDonald et al., 1995). Short sequences of rapid FM calls below 90 Hz are associated with animals in social groups (Moore et al., 1999; Mellinger and Clark, 2003). The most typical blue whale vocalizations are infrasonic sounds in the 15 or 17 to 20 Hz range (Sears and Perrin, 2009). The seasonality and structure of the vocalizations suggest that these are male song displays for attracting females and/or competing with other males. At SLs ranging 180 to 190 dB re 1 µPa @ 1 m, blue whale vocalizations are among the loudest made by any animal (Cummings and Thompson, 1971; Aroyan et al., 2000).

Blue whales produce long, patterned hierarchically organized sequences of vocalizations that are characterized as songs. Blue whales produce songs throughout most of the year with a peak period of singing overlapping with the general period of functional breeding. Blue whales also produce a variety of transient sound (i.e., they do not occur in predictable patterns or have much interdependence of probability) in the 30 to 100 Hz band (sometimes referred to as “D” calls). These usually sweep down in frequency or are inflected (up-over-down), occur throughout the year, and are assumed to be associated with socializing when animals are in close proximity (Mellinger and Clark, 2003; Clark and Ellison, 2004).

The call characteristics of blue whales vary geographically and seasonally (Stafford et al., 2001). It has been suggested that song characteristics could indicate population structure (McDonald et al., 2006b). In temperate waters, intense bouts of long, patterned sounds are common from fall through spring, but these also occur to a lesser extent during the summer in high-latitude feeding areas.

4.1.2 FIN WHALE (*BALAENOPTERA PHYSALUS*)

The fin whale is listed as endangered under the ESA, depleted under the MMPA, protected under CITES, and classified as endangered by the IUCN. The global population estimate is roughly 140,000 whales (Jefferson et al., 2008). In the western North Atlantic, there is an estimated 2,269 whales (Waring et al., 2009), while the population estimated for the central and eastern North Atlantic is 30,000 (IWC, 2009). The eastern North Pacific has an estimated 2,636 whales, and Hawaii has an estimated 174 fin whales (Carretta et al., 2009). The IWC (2009) estimates that 3,200 fin whales exist in West Greenland.

Fin whales are widely distributed in all oceans of the world. They are primarily found in temperate and cool waters. Fin whales migrate seasonally between higher latitudes for foraging and lower latitudes for mating and calving (Jefferson et al., 2008). Specific breeding areas are unknown and mating is assumed to occur in pelagic waters, presumably some time during the winter when the whales are in mid-latitudes. Foraging grounds tend to be near coastal upwelling areas and data indicate that some whales remain year round at high latitudes (Clark and Charif, 1998).

Fin whales reach sexual maturity between six and eight years of age, with mating occurring from December through February in the northern hemisphere and from May through July in the southern hemisphere (Aguilar, 2009). Birth occurs in tropical/subtropical breeding grounds. The movements of fin whales in the southern hemisphere are more definitive than for the northern hemisphere, with the whales conducting north-south seasonal migrations, feeding in summer and breeding and fasting through the winter (Aguilar, 2009). Although the movements of fin whales in the northern hemisphere are believed to follow a similar migrational pattern, it is more complex and not fully detailed. The waters of New England have been established as a major feeding ground for fin whales in the western north Atlantic during the late spring through summer, with summer feeding grounds having also been identified off northern Morocco, Gilbraltar Strait, northeastern Spain, Scotland, northern and western Norway, Newfoundland, Faroe Islands, and Iceland; no winter grounds are known for the North Atlantic (Aguilar, 2009; Waring et al., 2010). Fin whale aggregations have been documented year-round in the waters of southern/central California and the Gulf of California (Tershy et al., 1993; Forney et al., 1995; Barlow, 1997) while summer grounds in the northeastern Pacific have been observed off Oregon and the Gulf of Alaska (Green et al., 1992; McDonald, 1999). During winter months, fin whales have been observed over a wide geographic area from 23°N to 60°N, but the location of primary wintering areas are unknown. It appears likely that the two migratory stocks mingle in the Bering Sea in July and August. Acoustic data indicates that the waters of the U.S. Pacific coast are an important feeding area in the fall through winter for fin whales (Watkins et al., 2000; Moore et al., 2006; and Stafford et al., 2007). Although some fin whales have been acoustically recorded in Hawaiian waters during all months except June and July, fin whale sightings in those waters are very rare. Not all fin whales migrate seasonally, however; fin whales appear to occur year-round residents in the Gulf of California, East China Sea, and possibly in the Mediterranean Sea (Jefferson et al., 2008).

Swimming speeds average between 9.2 and 14.8 km/hr (5 to 8 kts) (Aguilar, 2009). Fin whales dive for a mean duration of 4.2 min at depths averaging 60 m (197 ft) (Croll et al., 2001a; Panigada et al., 2004). Maximum dive depths have been recorded deeper than 360 m (1,181 ft) (Charif et al., 2002). Fin whales forage at dive depths between 100 and 200 m (328 to 656 ft), with foraging dives lasting from 3 to 10 min (Aguilar, 2009).

There is no direct measurement of fin whale hearing sensitivity (Ketten, 2000; Thewissen, 2002). Fin whales produce a variety of LF sounds that range from 10 to 200 Hz (Watkins, 1981; Watkins et al., 1987; Edds, 1988; Thompson et al., 1992). Short sequences of rapid FM calls from 20 to 70 Hz are associated with animals in social groups (Watkins, 1981; Edds, 1988; McDonald et al., 1995). The most common fin whale vocalization is what is referred to as the “20-Hz signal”, which is a low frequency (18 to 35 Hz) loud and long (0.5 to 1.5 sec) patterned sequence signal (Patterson and Hamilton, 1964; Watkins et al., 1987; Clark et al., 2002). The pulse patterns of the 20-Hz signal vary geographically and with seasons (Clark et al., 2002; Croll et al., 2002). Regional differences in vocalization production and structure have been found between the Gulf of California and several Atlantic and Pacific Ocean regions. The 20-Hz signal is common from fall through spring in most regions, but also occurs to a lesser extent during the summer in high-latitude feeding areas (Clark and Charif, 1998; Clark et al., 2002). In the Atlantic region, 20-Hz signals are produced regularly throughout the year. Atlantic fin whales also produce higher frequency downsweeps ranging from 100 to 30 Hz (Frankel, 2009). Estimated SLs of the 20-Hz signal are as high as 180 to 190 dB re 1 µPa @ 1 m (Patterson and Hamilton, 1964; Watkins et al., 1987; Thompson et al., 1992; McDonald et al., 1995; Charif et al., 2002; Croll et al., 2002). Croll et al. (2002) verified the earlier conclusion of Watkins et al. (1987) that the 20-Hz vocalizations are only produced by male fin whales and likely are male breeding displays.

Croll et al. (2001b) studied the effects of anthropogenic low-frequency sound with RLs greater than 120 dB on the foraging ecology and vocalizations of blue and fin whales off San Nicolas Island, California. No obvious responses of either whale species was detected that could be attributable to the anthropogenic low-frequency sounds produced by SURTASS LFA sonar (Croll et al. 2001b).

4.1.3 SEI WHALE (*BALAENOPTERA BOREALIS*)

The sei whale is currently listed as endangered under the ESA, depleted under the MMPA, protected under CITES, and as endangered by the IUCN. The global population for the sei whale is estimated to be 80,000 whales (Jefferson et al., 2008). The population estimate in Nova Scotian waters is 207 whales (Waring et al., 2009), while the population of the central North Atlantic is estimated as 10,000 whales (Horwood, 2009). In the eastern North Pacific, an estimated 46 whales occur and 77 sei whales are estimated to occur in Hawaiian waters (Carretta et al., 2009).

Sei whales are primarily found in temperate zones of the world's oceans. In the North Atlantic, sei whales are located off Nova Scotia and Labrador during the summer and as far south as Florida during the winter (Leatherwood and Reeves, 1983). In the North Pacific, they range from the Gulf of Alaska to California in the east and from Japan to the Bering Sea in the west. Sei whales do not occur in high Arctic and Antarctic waters, with the Antarctic Convergence, southern Bering Sea, and waters from Greenland to Iceland to Norway forming the upper limits of their seasonal ranges (Horwood, 1987).

Sei whales reach maturity at 10 years of age with conception occurring dominantly in June in the southern hemisphere and in December in the northern hemisphere (Horwood, 2009), followed by a 10 to 12 month gestational period. Calving occurs in the mid-latitude regions of the species range (Jefferson et al., 2008). Sei whales follow the general annual north-south migrational pattern of most baleen whales, with feeding occurring during summer in polar regions and breeding occurring during winter in tropical to subtropical areas, with sei whales often observed near the equator in mid-winter (Horwood, 1987). Specific breeding grounds are not known for this species. Horwood (1987) suggested that sei whale migration is largely segregated by sexual class, with pregnant females arriving earlier and mature males remaining longer on the feeding grounds.

Sei whales are fast swimmers, surpassed only by blue whales (Sears and Perrin, 2009). Swim speeds have been recorded at 4.6 km/hr (2.5 kts), with a maximum speed of 25 km/hr (13.5 kts) (Jefferson et al., 2008). Dive times range from 0.75 to 15 min, with a mean duration of 1.5 min (Schilling et al., 1992). Sei whales make shallow foraging dives of 20 to 30 m (65 to 100 ft), followed by a deep dive up to 15 min in duration (Gambell, 1985).

There is no direct measurement of the hearing sensitivity of sei whales (Ketten, 2000; Thewisson, 2002). Sei whale vocalizations are the least studied of all the rorquals. Rankin and Barlow (2007) recorded sei whale vocalizations in Hawaii and reported that all vocalizations were downsweeps, ranging from on average from 100.3 to 446 Hz for "high frequency" calls and from 39.4 to 21.0 Hz for "low frequency" calls. In another study, McDonald et al. (2005) recorded sei whales in Antarctica with an average frequency of 433 Hz.

4.1.4 BRYDE'S WHALE (*BALAENOPTERA EDENI*)

The Bryde's whale is currently protected under CITES and classified as a data deficient species by the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. There are no global estimates for Bryde's whale. In the western North Pacific, the population of Bryde's whales is estimated by the IWC (2009) as 20,501 whales, while 10,000 whales are estimated in the eastern tropical Pacific (Jefferson et al., 2008). In Hawaiian waters, 493 Bryde's whales have been estimated (Carretta et al., 2009), and in the waters of the Gulf of Mexico, only 15 Bryde's whales are estimated to occur (Waring et al., 2009).

Bryde's whales occur roughly between 40°N and 40°S throughout tropical and warm temperate (>16.3°C [61.3°F]) waters of the Atlantic, Pacific, and Indian Oceans year round (Omura, 1959; Kato and Perrin, 2009). Bryde's whales occur in some semi-enclosed waters such as the Gulf of California, Gulf of Mexico, and East China Sea (Kato and Perrin, 2009). Bryde's whales migrate seasonally toward the lower latitudes near the equator in winter and to high latitudes in summer (Kato and Perrin, 2009). There is some evidence that Bryde's whales remain resident in areas off South Africa and California throughout the year, migrating only short distances (Best, 1960; Tershy, 1992).

While Bryde's whales basically follow the typical baleen whale pattern of migrating from high latitudes to the equator seasonally, some Bryde's whales also remain year-round in tropical to temperate waters. The breeding season for the Byrde's whale is not well defined and births occur throughout the year (Jefferson et al., 2008). Peaks in both births and conception occur in the winter among pelagic Bryde's (Kato and Perrin, 2009). Bryde's whales are known to breed off South Africa (Best, 1960 and 1975). Foraging grounds are not well known for this species.

Bryde's whales are relatively fast swimming whales. The maximum swim speed reached by a Bryde's whale was recorded at 20 to 25 km/hr (10.8 to 13.5 kts), with average swim speeds reported between 2 and 7 km/hr (1.1 and 3.8 kts) (Kato and Perrin, 2009). Bryde's whales can dive to a water depth of about 300 m but dive durations are not well known (Kato and Perrin, 2009).

There is no direct measurement of the hearing sensitivity of Bryde's whales (Ketten, 2000). Bryde's whales are known to produce a variety of LF sounds ranging from 20 to 900 Hz, with the higher frequencies being produced between calf-cow pairs (Cummings, 1985; Edds et al., 1993). Oleson et al. (2003) reported call types with a fundamental frequency below 60 Hz. These lower frequency call types have been recorded from Bryde's whales in the Caribbean, eastern tropical Pacific, and off the coast of New Zealand. Calves produce discrete pulses at 700 to 900 Hz (Edds et al., 1993). SLs range between 152 and 174 dB re 1 µPa @ 1 m (Frankel, 2009). Although the function of Bryde's whale vocalizations is not known, communication is the assumed purpose.

4.1.5 MINKE WHALE (*BALAENOPTERA ACUTOROSTRATA*)

The minke whale is protected under CITES and classified by the IUCN as a least concern (lower risk) species. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. Populations are estimated at 180,000 in the Northern Hemisphere (Jefferson et al., 2008). Regional stock assessments report approximately 3,312 animals off the Canadian east coast and 806 animals of the coasts of California, Oregon, and Washington (Waring et al., 2009; Carretta et al., 2009). Three stocks of minke whales are recognized in the North Pacific by the IWC. The first stock is the Sea of Japan/East China Sea stock, the second is the western Pacific stock, west of 180°W longitude, and the third is referred to as the "remainder" stock which consists of whales east of 180°W longitude. The NMFS reports that in this remainder area, minke whales are common in the Bering Sea, the Chukchi Sea, and in the Gulf of Alaska, but they are not considered abundant in any other part of the eastern Pacific Ocean. Minke whales are generally found over continental shelf waters; and in the far north, they are believed to be migratory, but appear to have home ranges in the inland waters of Washington and central California (Dorsey et al., 1990). Similar to other balaenopterids, minke whales migrate during late spring through early fall to higher latitudes where they feed, and to lower latitudes where they breed during the fall and winter. Lockyer (1981) recorded average swimming speeds of 6.1 km/hr (3.3 kts). Maximum dive duration in minke whales is 15 min, with an average dive time of 6 to 12 min.

Some populations of minke whales in both the northern and southern hemispheres migrate seasonally beginning in spring from high latitude summer feeding grounds to tropical winter breeding grounds, where they overwinter; the migrational patterns of minke whales is not as well defined as those of the larger baleen whales (Jefferson et al., 2008; Glover et al., 2010). Some minke whales remain resident year-round, such as the minke whales that occur in inland Washington, California, and Gulf of California waters (Caretta et al., 2011). Calving is thought to occur in dispersed low latitude areas during winter months following a gestational period of about 10 to 11 months. Peak birthing months are July and August (Perrin and Brownell, 2009). Antarctic minke whales are common along the ice edge where they feed in the austral summer, with some whales overwintering in Antarctic waters; during the austral winter, most Antarctic minkes migrate to breeding grounds at mid-latitudes between 170°E to 100°W and 10 to 30°S in the Pacific, off northeastern and eastern Australia, off western South Africa, and off northeastern Brazil in the Atlantic (Perrin and Brownell, 2009). In the North Atlantic, wintering grounds are not well known but are believed to extend from the tropical waters of the Caribbean Sea to Gibraltar, while summer feeding grounds are known in New England waters (Waring et al., 2010).

There is no direct measurement of the hearing sensitivity of minke whales (Ketten, 2000; Thewisson, 2002). Minke whales produce a variety of sounds, primarily moans, clicks, downsweeps, ratchets, thump trains, and grunts in the 80 Hz to 20 kHz range (Winn and Perkins, 1976; Thompson et al., 1979; Edds-Walton, 2000; Mellinger and Clark, 2000; Frankel, 2009). The signal features of their vocalizations consistently include low frequency, short-duration downsweeps from 250 to 50 Hz. Thump trains may contain signature information, and most of the energy of thump trains is concentrated in the 100 to 400 Hz band (Winn and Perkins, 1976; Mellinger et al., 2000). Complex vocalizations recorded from Australian minke whales involved pulses ranging between 50 Hz and 9.4 kHz, followed by pulsed tones at 1.8 kHz and tonal calls shifting between 80 and 140 Hz (Gedamke et al., 2001). The minke whale was identified as the elusive source of the North Pacific “boing” sound during a research cruise off Hawaii (Rankin and Barlow, 2005).

Both geographical and seasonal differences have been found among the sounds recorded from minke whales. Sounds recorded in the Northern Hemisphere, include grunts, thumps, and ratchets from 80 to 850 Hz, and pings and clicks from 3.3 to 20 kHz. Most sounds recorded during the winter consist of 10 to 60 sec sequences of short 100 to 300 microsecond LF pulse trains (Winn and Perkins, 1976; Thompson et al., 1979; Mellinger and Clark, 2000), while Edds-Walton (2000) reported LF grunts recorded during the summer. Recordings in mid- to high latitudes in the Ross Sea, Antarctica, have short sounds, sweeping down in frequency from 130 to 60 Hz over 0.2 to 0.3 sec. Similar sounds with a frequency range from 396 to 42 Hz have been recorded in the Saint Lawrence Estuary (Edds-Walton, 2000). The function of the sounds produced by minke whales is unknown, but they are assumed to be used for communication such as maintaining space among individuals (Richardson et al., 1995).

4.1.6 HUMPBACK WHALE (*MEGAPTERA NOVAEANGLIAE*)

The humpback whale is listed as endangered under the ESA, depleted under the MMPA, protected under CITES, and classified as a least concern (lower risk) species by the IUCN. The global population of the humpback whale is estimated to be between 35,000 to 40,000 whales (Jefferson et al., 2008). Stevick et al. (2003) estimated the population of North Atlantic humpback whales to be 11,570 while Øien (2008) estimated 1,059 humpbacks occur in Norwegian waters and the Barents Sea. The stock of humpback whales in the Gulf of Maine is estimated as 847 individuals (Waring et al., 2009). In the north Pacific Ocean, there are an estimated 1,391 whales in the California/Oregon/Washington stock while 394 humpback whales are estimated in the western North Pacific stock (Angliss and Allen, 2009; Carretta et al., 2009). Calambokidis et al. (2008) recently estimated the population of humpback whales in the entire North Pacific as 18,302 individuals.

Humpback whales are distributed throughout the world’s oceans and are only absent from high Arctic waters and some equatorial waters. Humpback whales are found in coastal shelf waters when feeding and close to islands and reefs when breeding (Clapham, 2009). Humpback whales are highly migratory, occurring on their feeding grounds in mid- to high-latitudes from spring through early fall and traveling to calving grounds in tropical waters in fall, where they typically overwinter. Humpback whales have been documented travel over 8,047 km (4,345 nmi) during one leg of their seasonal migrations, which is the longest known migration of any mammal (Palsbøll et al, 1997). Data indicate that not all humpbacks migrate during the fall from summer feeding to winter breeding sites and that some whales remain year round at high latitudes (Christensen et al., 1992; Clapham et al., 1993). Barco et al. (2002) reported on humpback whale population site fidelity in the waters off the U.S. mid-Atlantic states.

Individual whales in the northern Atlantic Ocean have shown a strong fidelity to specific feeding grounds, including the Gulf of Maine, Newfoundland/Labrador, the Gulf of Saint Lawrence, western Greenland, Iceland, and northern Norway, where humpbacks spend spring through fall months foraging (Katona and Beard, 1990; Christensen et al., 1992). Humpback whales have well-defined breeding areas in tropical waters that are usually located near isolated islands. Humpback whales migrate from their northern Atlantic feeding grounds to a winter breeding range in the West Indies, the Cape Verde Islands, and off northwest Africa. In the West Indies, the majority of whales are found in the waters of the Dominican Republic, notably on Silver Bank and Navidad Bank, and in Samana Bay (Balcomb and Nichols, 1982; Whitehead and Moore, 1982; Mattila et al. 1994). In the North Pacific, there are breeding grounds around the Mariana Islands, Bonin, Ogasawara, Okinawa, Ryukyu Island, and Taiwan (Clapham, 2009). In the eastern North Pacific, breeding grounds occur around the Hawaiian Islands, off the tip of Baja California, and off the Revillagigedo Islands (Clapham, 2009).

Humpback whales swim with mean speeds near 4.5 km/hr (2.4 kts) (Gabriele et al., 1996). Dive times recorded off southeast Alaska are near 3 to 4 min in duration (Dolphin, 1987). In the Gulf of California, humpback whale dive times averaged 3.5 min (Strong, 1990). The deepest recorded humpback dive was 240 m (790 ft), with most dives between 60 and 120 m (197 to 394 ft) (Hamilton et al., 1997).

No direct measurements of the hearing sensitivity of humpback whales exist (Ketten, 2000; Thewissen, 2002). Due to this lack of auditory sensitivity information, Houser et al. (2001) developed a mathematical function to describe the frequency sensitivity by integrating position along the humpback basilar membrane with known mammalian data. The results predicted the typical U-shaped audiogram with sensitivity to frequencies from 700 Hz to 10 kHz with maximum sensitivity between 2 to 6 kHz. Humpback whales have been observed reacting to LF industrial noises at estimated RLs of 115 to 124 dB (Malme et al., 1985). They have also been observed to react to conspecific calls at RLs as low as 102 dB (Frankel et al., 1995).

Humpbacks produce a great variety of sounds that fall into three main groups: 1) sounds associated with feeding; 2) sounds made within groups on winter grounds; and 3) songs associated with reproduction. These vocalizations range in frequency from 20 to 10,000 Hz. Feeding groups produce distinct repeated sounds ranging from 20 to 2,000 Hz, with dominant frequencies near 500 Hz (Thompson et al., 1986; Frankel, 2009). These sounds are attractive and appear to rally animals to the feeding activity (D'Vincent et al., 1985; Sharpe and Dill, 1997). Feeding sounds were found to have SLs in excess of 175 dB (Thompson, et al., 1986; Richardson et al., 1995). Social sounds in the winter breeding areas are produced by males and range from 50 Hz to more than 10,000 Hz with most energy below 3,000 Hz (Tyack and Whitehead, 1983; Richardson et al., 1995). These sounds are associated with agonistic behaviors from males competing for dominance and proximity to females. They are known to elicit reactions from animals up to 9 km (4.9 nmi) away (Tyack and Whitehead, 1983).

During the breeding season, males sing long complex songs with frequencies between 25 and 5,000 Hz. Mean SLs are 165 dB (broadband), with a range of 144 to 174 dB (Payne and Payne, 1971; Frankel et al., 1995; Richardson et al., 1995; Tyack and Clark, 2000). The songs vary geographically among humpback populations and appear to have an effective range of approximately 10 to 20 km (5.4 to 10.8 nmi) (Au et al., 2000). Singing males are typically solitary and maintain spacing of 5 to 6 km (2.7 to 3.2 nmi) apart (Tyack, 1981; Frankel et al., 1995). Songs have been recorded on the wintering ground, along migration routes, and less often on northern feeding grounds (Richardson et al., 1995).

Gabriele and Frankel (2002) reported that underwater acoustic monitoring in Glacier Bay National Park, Alaska, has shown that humpback whales sing more frequently in the late summer and early fall than previously thought. A song is a series of sounds in a predictable order. Humpback songs are typically about 15 min long and are believed to be a mating-related display performed only by males. This study showed that humpback whales frequently sing while they are in Glacier Bay in August through November. Songs were not heard earlier than August, despite the presence of whales, nor later than November, possibly because the whales had started to migrate. It is possible that song is not as prevalent in the spring as it is in the late summer and fall; however, whales still vocalize at this time. The longest song session was recorded in November and lasted almost continuously for 4.5 hours, but most other song sessions were shorter. The songs in Hawaii and Alaska were similar within a single year. The occurrence of songs possibly correlates to seasonal hormonal activity in male humpbacks prior to the migration to the winter grounds.

4.1.7 BOWHEAD WHALE (*BALAENA MYSTICETUS*)

Until recently, five stocks of bowhead whales were recognized for management purposes: Spitsbergen, Davis Strait, Hudson Bay, Okhotsk Sea, and Bering-Chukchi-Beaufort Seas (or western Arctic) stocks (Rugh et al., 2003). However, recent genetic, tagging, and population-survey research indicates that the Davis Strait and Hudson Bay stocks should be classified as the same stock (Heide-Jørgensen et al., 2006; Allen and Angliss, 2010). Only the Okhotsk Sea stock of bowhead whales is located in a region where SURTASS LFA sonar operations potentially may be conducted. Currently, bowheads in the Okhotsk Sea stock do not move beyond the confines of the sea, so this stock remains isolated with no intermingling occurring with the western Arctic stock.

Throughout its range, the bowhead whale is listed under the ESA as endangered and under the MMPA as depleted. While all bowhead stocks are listed on the IUCN Red List, the Okhotsk Sea stock is considered endangered (Reilly et al., 2008). The pre-whaling abundance of bowhead whales in the Sea of Okhotsk is unknown, but Mitchell's (1977) estimate of about 6,500 bowheads is the most commonly used estimate. Currently, there is no reliable abundance estimate for bowhead whales in the Sea of Okhotsk, but the population is considered mature but small, with tentative estimates ranging from 150 to 400 bowhead whales (Reilly et al., 2008; NMFS, 2009; Ivashchenko and Clapham, 2010). The IWC has noted that the Okhotsk Sea stock has shown no significant signs of recovery from whaling exploitation (IWC; 2010).

Bowhead whales are distributed in arctic to sub-arctic waters of the northern hemisphere roughly between 55° and 85°N (Jefferson et al., 2008). Bowheads typically occur in or near sea/pack ice, with their seasonal distribution being strongly influenced by the location of pack ice (Moore and Reeves, 1993). Typically, bowheads move southward in autumn and winter with the advancing ice edge and remain near the ice edge, in polynyas, or areas of unconsolidated pack ice. Moving northward in spring and summer, bowheads concentrate on feeding in areas of high zooplankton abundance.

Bowhead whales occur year-round in the Sea of Okhotsk but little is known about their winter distribution or whether seasonal movements occur (Braham, 1984). Today, bowhead whales are found only in the northern Sea of Okhotsk, with the following principal regions of occurrence in the northwestern and northeastern sea: Shantar region (including Academy, Tugurskiy, Ulbanskiy, and Nikolay Bays) to the Kashevarova Bank (located between Sakalin and Iona Islands), Shelikhov Bay, and Gizhiginskaya Bay; formerly, bowhead occurrence ranged as far northward as Penzhinskaya Bay (Braham, 1984; Rice, 1998; Rogachev et al., 2008; Ivashchenko and Clapham, 2010). Bowheads have been observed in the northern sea in January and February; winter sightings so far north have lead to the speculation that some bowheads may spend the winter among the ice (Ivashchenko and Clapham, 2010). By summer and into early fall (June through September), most sightings of bowhead whales have occurred in northwestern Okhotsk Sea in the Shantar region (Rogachev et al., 2008; Ivashchenko and Clapham, 2010). Unlike other regions, bowheads occupy areas that are ice-free during summer in the Sea of Okhotsk (Reilly et al., 2008). In the joint Japanese-Russian summer sighting surveys from 1989 through 2002 across the entire Okhotsk Sea, including the southern sea, Miyashita et al. (2005) report that no bowhead whales were observed.

Dive behavior of bowhead whales varies widely by season, feeding depth, and life history stage (age and reproductive status) but exhibits no diel pattern (Krutzikowsky and Mate, 2000; Thomas et al., 2003; Heide-Jorgensen et al., 2003). Bowheads are excellent divers, capable of remaining submerged for 61 minutes and diving to depths as deep as 416 m (1,365 ft) (Krutzikowsky and Mate, 2000; Heide-Jorgensen et al., 2003). The majority of bowhead dives appear to be shallow and short dives, at depths

≤16 m (53 ft) for a mean duration of 6.9 to 14.1 minutes (Krutzikowsky and Mate, 2000). Heide-Jorgensen et al. (2003) reported that fewer than 15% of all recorded bowhead dives were to depths greater than 152 m and only 5% of the dives lasted more than 24 minutes. Averaging about 1.1 to 5.8 km/hr (0.6 to 3 kts), bowhead whales are fairly slow swimmers (Mate et al., 2000). They can, however, travel vast distances, with one tagged bowhead whale having traveled 3,386 km (1,828 nmi) in 33 days at an overall swim speed of 5 km/hr (2.7 kts) (Mate et al. 2000).

Knowledge of mysticete hearing is very limited. No direct physiological or behavioral measurements of bowhead whale hearing have been made (Ketten, 1997). Norris and Leatherwood (1981) described the unique auditory morphology of the bowhead whale and determined that bowhead whales are adapted to hear frequencies ranging from high infrasonic to low ultrasonic. Mysticete hearing sensitivity is often inferred from behavioral responses to sound and from the vocalization ranges a species uses. Richardson (1995) estimated from observations of behavioral reactions that mysticete whales likely hear sounds predominantly in the 50 to 500 Hz range, while Ketten (2000) reported that baleen whales likely have best hearing in the frequency range where their vocalizations have the greatest energy, below 5 kHz.

Bowhead whales produce a variety of vocalizations that Frankel (2009) classifies in two principal groups: simple low frequency, frequency-modulated (FM) calls and complex calls. The FM calls, or moans, are always less than 400 Hz, typically have a duration of 2.5 seconds, and are typified by up-and down-swept, constant FM contours (Au and Hastings, 2008; Frankel, 2009). Cummings and Holliday (1987) measured the source level of bowhead moans at a mean of 177 dB re 1 µPa @ 1 m. The complex calls are a combination of pulsed, pulsed-tonal, and high calls; high calls have frequencies >400 Hz and sound like a whine, while the pulsed tonal call is both FM and amplitude modulated (AM), and the pulsed call is often <400 Hz but can range to 1,000 Hz with a mixture of pulsed AM and FM pulses (Frankel, 2009). The pulse modulated call has been described as a gargle type sound with a measured peak source level between 152 to 169 dB re 1 µPa @1 m (Cummings and Holliday, 1987).

Bowheads also emit sequential sounds with repeatable phrases or patterned signals that can be classified as songs; bowhead whales were the second mysticete whale species discovered to produce songs (Au and Hastings, 2008). Bowhead whales sing one to two themes with the songs changing substantially seasonally and annually (Frankel, 2009; Tervo et al., 2009). Bowhead singing has now been recorded in spring, fall, and winter and may be associated with seasonal movements but also courtship behavior (Delarue et al., 2009; Tervo et al., 2009). Previously, recordings have indicated that the same basic song version with considerable individual variability is sung during a year by all bowhead whales in a population or region but more recently, Stafford et al. (2008) and Delarue et al. (2009) have recorded two songs being sung at a given time. Songs are composed of FM and AM components with great variation in tone (Frankel, 2009). Cummings and Holliday (1987) reported that the mean duration of a song was 66.3 seconds, but song bouts, or the repetition of the same song, can last for hours (Delarue et al., 2009). Several purposes for bowhead vocalizations have been suggested including communication and group cohesion. Bowhead whales may also use the reverberation of their calls off surface ice to assess ice conditions (location and smoothness) to avoid collisions with thick ice keels or to locate smooth ice that is thin enough to break through to breathe (George et al., 1989).

4.1.8 NORTH ATLANTIC RIGHT WHALE (*EUBALAENA GLACIALIS*)

The North Atlantic right whale is listed as endangered under the ESA, depleted under the MMPA, protected under CITES, and as endangered under the IUCN. The eastern North Atlantic right whale stock has not recovered over the last century and is considered extirpated (Waring et al., 2009). The western North Atlantic stock is extremely endangered with the best abundance estimated for 2008 as 438 individual individuals (NARWC, 2009). Critical habitat for this species is designated under the ESA in two geographic locations off the eastern U.S: 1) Southeast U.S. coastal waters between southern Georgia and northern Florida; 2) Northeastern U.S. waters of the Great South Channel (and southern Gulf of Maine) and Cape Cod and Massachusetts Bays (NOAA, 1994).

North Atlantic right whales are found in temperate to subpolar waters of the North Atlantic Ocean from Florida and the Cape Verde Islands northward to Iceland and Greenland (Jefferson et al., 2008). They are most commonly found around coastal and continental shelf waters of the western North Atlantic from Florida to Nova Scotia (Kenney, 2009). From late fall to early spring, right whales breed and give birth in temperate shallow areas and then migrate into higher latitudes where they feed in coastal waters during the late spring and summer. Right whales have been known to occasionally move offshore into deep water, presumably for feeding (Mate et al., 1997). North Atlantic right whales calve in the nearshore waters from northeastern Florida to southeastern Georgia, where critical habitat is located. Not all right whales are found in southeastern U.S. waters in the winter, but the location where the remainder of the population overwinters is unknown. In the north Atlantic, right whales feed predominantly in New England waters including the Great South Channel, Cape Cod and Massachusetts Bays, Stellwagen Bank, Georges Bank, Gulf of Maine, as well as in the Canadian Bay of Fundy, Roseway Basin, Scotian Shelf, and the Gulf of St. Lawrence (IFAW, 2001; Vanderlaan et al., 2003; Waring et al., 2010). Right whales have been documented making long-distance movements into Icelandic, Norwegian, and Greenlandic waters; these long-distance movements indicate an extended range for at least some individual right whales and the existence of important habitat areas not presently well described (Waring et al., 2010).

Mate et al. (1997) studied satellite-monitored movements of North Atlantic right whales in the Bay of Fundy. Of the nine whales tracked, six whales left the Bay of Fundy at least once and had an average speed of 3.5 km/hr (1.9 kts), while those that remained in the Bay of Fundy had a swim speed average of 1.1 km/hr (0.6 kts). The three whales that did not leave the Bay of Fundy still traveled more than 2,000 km (1,080 nmi) before returning to their original tagging area. All of these whales were in or near shipping lanes and moved along areas identified as right whale habitat (Mate et al., 1997). Baumgartner and Mate (2003) studied diving behavior of foraging North Atlantic right whales in the lower Bay of Fundy and found that the average foraging dive time was 12.2 min, with a maximum dive of 16.3 min. The average dive depth for foraging dives was 121 m (398 ft), with a maximum depth of 174 m (571 ft). However, the maximum dive depth recorded by North Atlantic right whales was 306 m (1,000 ft) (Mate et al., 1992).

No direct measurements of the hearing sensitivity of right whales exist (Ketten, 2000; Thewissen, 2002). However, thickness or width measurements of the basilar membrane suggest their hearing range is 10 Hz to 22 kHz, based on established marine mammal models (Parks et al., 2007). North Atlantic right whales produce LF moans with frequencies ranging from 70 to 600 Hz (Vanderlaan et al., 2003). Lower frequency sounds characterized as calls are near 70 Hz. Broadband sounds have been recorded during surface activity and are termed “gunshot slaps” (Clark, 1982; Matthews et al., 2001). Parks and Tyack (2005) describe North Atlantic right whale vocalizations from surface active groups (SAGs) recorded in the Bay of Fundy, Canada. The call-types defined in this study included screams, gunshots, blows, up calls, warbles, and down calls and were from 59 whale sounds measured at ranges between 40 and 200 m (31 to 656 ft), with an average distance of 88 m (289 ft). The SLs for the sounds ranged from 137 to 162 dB for tonal calls and 174 to 192 dB for broadband gunshot sounds.

4.1.9 NORTH PACIFIC RIGHT WHALE (*EUBALAENA JAPONICA*)

The North Pacific right whale is listed as endangered under the ESA, depleted under the MMPA, and protected under CITES. The North Pacific right whale is also classified as endangered under the IUCN. There are no reliable population estimates for the North Pacific right whale, but it is estimated that there are no more than a few hundred North Pacific right whales in the North Pacific Ocean (Angliss and Allen, 2009). Two stocks have been identified for this right whale, an eastern (southeastern Bering Sea and northern Gulf of Alaska) and western stock (Sea of Okhotsk) (Allen and Angliss, 2011). A population estimate is currently in preparation for the eastern stock, but at least 17 distinct individuals have been documented (Allen and Angliss, 2011). Critical habitat for this species is designated under the ESA in two geographic locations: 1) Bering Sea and 2) western Gulf of Alaska (50 CFR § 226.215).

The North Pacific right whale is not a very well known species because the remaining population consists of so few whales. This species is often found in continental shelf waters but also occurs in oceanic waters. From historic records, North Pacific right whales were recorded in offshore waters with a northward migration in the spring and southward migration in autumn (Jefferson et al., 2008). This whale population is primarily sighted in the Sea of Okhotsk and the eastern Bering Sea (Kenney, 2009). The western stock of right whales feeds principally in the Sea of Okhotsk (Allen and Angliss, 2011). Since 1996, North Pacific right whales have been observed consistently in the southeastern Bering Sea (Goddard and Rugh, 1998). Analysis of acoustic recorder data deployed from October 2000 to January 2006 and May 2006 to April 2007 indicates that right whales remain in the southeastern Bering Sea from May through December with peak call detection in September (Munger and Hildebrand, 2004; Stafford and Mellinger, 2009). Rates of detection on the middle shelf (<100 m depth) suggests that right whales pass through intermittently and typically do no remain longer than a few days (Munger and Hildebrand 2004, Munger et al. 2008). Right whale calls were rarely detected in the northwestern Gulf of Alaska in the late summer (Mellinger et al., 2004). The sightings and acoustic detection of right whales east of Kodiak Island in the Gulf of Alaska indicates at least occasional continuing use of this area (Allen and Angliss, 2011). Current migratory patterns of North Pacific right whales are unknown, although they are thought to migrate from high-latitude feeding grounds in summer to more temperate waters during the winter, possibly well offshore (Scarff, 1986, Clapham et al., 2004). Breeding grounds for this species are unknown. No winter coastal calving grounds in the eastern North Pacific have been identified (Scarff, 1986), leading to speculation that North Pacific right whales may breed offshore. Feeding grounds for the North Pacific right whale are poorly known, but are most likely in the Sea of Okhotsk, southeastern Bering Sea, and northwestern Gulf of Alaska; these areas are most pelagic than the feeding grounds documented for the North Atlantic right whale (Kenney, 2009). There is no swim speed or dive information available for the North Pacific right whale.

There is no direct measurement of the hearing sensitivity of right whales (Ketten, 2000; Thewissen, 2002). However, thickness measurements of the basilar membrane of North Atlantic right whale suggests a hearing range from 10 Hz to 22 kHz, based on established marine mammal models (Parks et al., 2007); this same range can be used as a proxy for North Pacific right whales. McDonald and Moore (2002) studied the vocalizations of North Pacific right whales in the eastern Bering Sea using autonomous seafloor-moored recorders. This study described five vocalization categories: up calls, down-up calls, down calls, constant calls, and unclassified vocalizations. The up call was the predominant type of vocalization and typically swept from 90 Hz to 150 Hz. The down-up call swept down in frequency for 10 to 20 Hz before it became a typical up call. The down calls were typically interspersed with up calls. Constant calls were also interspersed with up calls. Constant calls were also subdivided into two categories: single frequency tonal or a frequency waver of up and down, which varied by approximately 10 Hz. The down and constant calls were lower in frequency than the up calls, averaging 118 Hz for the down call and 94 Hz for the constant call (McDonald and Moore, 2002).

4.1.10 SOUTHERN RIGHT WHALE (*EUBALAENA AUSTRALIS*)

The southern right whale is listed as endangered under the ESA, depleted under the MMPA, and protected under CITES. The southern right whale is also classified as a least concern (lower risk) species under the IUCN. Multiple stocks of southern right whales have been proposed, including those in Argentina/Brazil, western and southeastern Australia, South Africa, east Africa/Mozambique, New Zealand, and Chile, but the best studied are those stocks in Argentina, South Africa, and Australia (Kenney, 2009). Although data from all stocks are not available, the current estimate of the population size of southern right whales is 15,000 whales (Kenney, 2009).

Southern right whales have a circumpolar distribution in the mid-latitudes of the southern hemisphere and are predominately found off Argentina, Chile, South Africa, and Australia (Kenney, 2009). Off Australia, southern right whales have been observed primarily in the coastal waters of West and South Australia and to a lesser extent off Tasmania, New South Wales, and Victoria (Bannister, 2001). Southern right whales are found off Chile in three principal locations, north of 47°S, Magellan Strait and Beagle Channel, and Drake Passage and Antarctica with highest occurrence from August and October (Aguayo-Lobo et al., 2008). Southern right whales move seasonally between warm water calving grounds and colder water feeding grounds. Major breeding areas include southern Australia, southern South America along the Argentine coast, and along the southern coast of South Africa (Croll et al., 1999). Feeding grounds appear to be located in offshore, pelagic waters in areas of high productivity (Kenney, 2009). Shallow coastal waters and bays in Argentina, are known winter calving grounds for the southern right whale and some mating behavior occurs in or near the calving grounds (Jefferson, et al., 2008; Kenney, 2009). Known breeding grounds include Peninsula Valdes, Argentina, Australia, and South Africa, with calving occurring from June to October, with a peak in August off South Africa (Best, 1994). There is no swimming or diving information available for the southern right whale.

There is no direct measurement of the hearing sensitivity of right whales (Ketten, 2000; Thewissen, 2002). However, thickness or width measurements of the basilar membrane suggest their hearing range is 10 Hz to 22 kHz, based on established marine mammal models (Parks et al., 2007). Southern right whales produce a great variety of sounds, primarily in the 50 to 500 Hz range, but they also exhibit higher frequencies near 1,500 Hz (Payne and Payne, 1971; Cummings et al., 1972). "Up" sounds are tonal frequency-modulated calls from 50 to 200 Hz that last approximately 0.5 to 1.5 sec and are thought to function in long-distance contact (Clark, 1983). Tonal downsweeps are also produced by this species. Sounds are used as contact calls and for communication over distances of up to 10 km (5.3 nmi) (Clark, 1980, 1982, 1983). For example, females produce sequences of sounds that appear to attract males into highly competitive mating groups. Maximum SLs for calls have been estimated at 172 to 187 dB (Cummings, et al. 1972; Clark, 1982).

4.1.11 PYGMY RIGHT WHALE (*CAPEREA MARGINATA*)

The pygmy right whale is protected under CITES and classified as least concern (lower risk) under IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. There are no available data on abundance estimates for this species. Very little is known about the pygmy right whale, and no abundance estimates are available.

The pygmy right whale is found only in temperate to polar waters of the southern hemisphere of the Atlantic, Pacific, and Indian oceans, generally north of the Antarctic Convergence (Jefferson et al., 2008). It has been recorded in coastal and oceanic regions, including areas of southern Africa, South America, Australia, and New Zealand (Kemper, 2009). Pygmy right whales occur in Tasmania throughout the year and during the southern winter off South Africa, particularly between False Bay and Algoa Bay (Leatherwood and Reeves, 1983; Evans, 1987). There is some evidence for inshore seasonal movements in spring and summer, possibly related to the availability of food, but no long-distance migration has been documented. Records of pygmy right whales for up to two months close to shore are suggestive of possible foraging activity (Kemper, 2009). There is no available literature on locations of breeding areas or mating and calving seasons (Ross et al., 1975; Lockyer, 1984; Baker, 1985). Records show this species swims at a speed of 5.4 to 9.4 km/hr (2.9 to 5.1 kts) and dives up to 4 min (Kemper, 2009). There is no information available on the dive depths of pygmy right whales.

There is no direct measurement of the hearing sensitivity of pygmy right whales (Ketten, 2000; Thewissen, 2002). Sounds produced by one solitary captive juvenile were recorded from 60 to 300 Hz (Dawbin and Cato, 1992). This animal produced short thump-like pulses between 90 and 135 Hz with a downsweep in frequency to 60 Hz. No geographical or seasonal differences in sounds have been documented. Estimated SLs were between 153 and 167 dB (Frankel, 2009).

4.1.12 GRAY WHALE (*ESCHRICHTIUS ROBUSTUS*)

The gray whale population is divided into two different stocks. The eastern North Pacific stock of gray whales was listed as endangered under the ESA, but was de-listed in 1994. The eastern stock is not categorized as depleted under the MMPA. The western North Pacific stock is extremely small, is still listed as endangered by the ESA, and is categorized as depleted under the MMPA. Gray whales are protected under CITES and classified as a least concern (lower risk) species under IUCN. The western North Pacific stock was thought to be extinct, but a small group of less than 100 gray whales still remain (Jefferson et al., 2008). The eastern North Pacific stock of gray whales is estimated to be 18,178 whales along the west coast of the United States (Angliss and Allen, 2009).

Gray whales are confined to the shallow coastal waters of the North Pacific and adjacent seas as far north as Beaufort and Chukchi Seas. In the eastern North Pacific, they occur as far south as the Baja California and as far north as the Beaufort and Chukchi Seas (Jefferson et al., 2008). The western stock occurs as far south as Japan in the western North Pacific and as far north as Korea and the Sea of Okhotsk (Jones and Swartz, 2009). Every year most of the population makes an extensive north-south migration from high-latitude feeding grounds to low-latitude breeding grounds. The Eastern North Pacific stock winters mainly along the west coast of Baja California, using certain shallow, nearly landlocked lagoons and bays, and calves are born from early January to mid-February (Rice et al., 1981), often seen on the migration well north of Mexico (Shelden et al., 2004). The northbound migration of the eastern stock generally begins in mid-February and continues through May (Rice et al. 1981, Poole, 1984), with cows and newborn calves migrating northward primarily between March and June along the U.S. West Coast. Gray whales from the western North Pacific spend June through November on their Arctic feeding grounds while most of those in the eastern North Pacific stock spend May through October foraging in polar waters, although some gray whales have been reported feeding in the waters of the Gulf of Alaska, southeastern Alaska, and off the Pacific coasts of the U.S. and Canada (Jones and Swartz, 2009; Allen and Angliss, 2011). Foraging grounds for the western North Pacific gray whale lie off Russia (Sakalin Island and the Kamchatka Peninsula) (Jones and Swartz, 2009). Most gray whales in the eastern Pacific breed or calve during the winter in lagoons of Baja California but breeding/calving grounds for the western north Pacific stock are not known (Jones and Swartz, 2009). Mating and calving are strongly synchronized with the seasonal migratory cycle.

Swim speeds during migration average 4.5 to 9 km/hr (2.4 to 4.9 kts) and when pursued may reach about 16 km/hr (8.64 kts) (Jones and Swartz, 2009). Gray whales generally are not long or deep divers. Traveling-dive times are 3 to 5 min with prolonged dives from 7 to 10 min, with a maximum dive time of 26 min, and a maximum dive depth recorded at 170 m (557 ft) (Jones and Swartz, 2009).

There are sparse data on the hearing sensitivity of gray whales. Dahlheim and Ljungblad (1990) suggest that free-ranging gray whales are most sensitive to tones between 800 and 1,500 Hz. Migrating gray whales showed avoidance responses at ranges of several hundred meters to LF playback SLs of 170 to 178 dB when the source was placed within their migration path at about 2 km (1.1 nmi) from shore. However, this response did not occur when the source was moved out of their migration path but occurred when the SL increased to duplicate the animals' RL within their migration corridor (Clark et al., 1999).

Gray whales produce a variety of sounds from about 100 Hz, potentially up to 12 kHz (Jones and Swartz, 2009). The most common sounds recorded during foraging and breeding are knocks and pulses in frequencies from <100 Hz to 2 kHz, with most energy concentrated at 327 to 825 Hz (Richardson et al., 1995). Tonal moans are produced during migration in frequencies ranging between 100 and 200 Hz (Jones and Swartz, 2009). Combinations of clicks and grunts have also been recorded from migrating gray whales in frequencies ranging below 100 Hz to above 10 kHz (Frankel, 2009). The seasonal variation in the sound production is correlated with the different ecological functions and behaviors of the gray whale. Whales make the least amount of sound when dispersed on the feeding grounds and are most vocal on the breeding-calving ground. The SLs for these sounds range between 167 and 188 dB (Frankel, 2009).

Moore and Clarke (2002) reviewed information on how offshore oil and gas activities, commercial fishing and vessel traffic, and whale watching and scientific research affected gray whales. The underwater noise sources played during these experiments included helicopter overflights, drill ship operations, drilling and production platforms, a semi-submersible drilling rig, and tripping operations. Malme et al. (1984, 1988) also conducted experiments using air gun arrays and single air guns. The gray whales' responses to the noise playback experiments and air gun shots include changes in swimming speed and changes in direction (away from the sound sources) (Malme et al., 1984). Changes in feeding with a resumption of feeding after exposure, changes in call rates and structure, and changes in surface behavior were also observed (Dahlheim, 1987; Malme et al., 1988; Moore and Clarke, 2002).

4.2 ODONTOCETES

Six families containing over 54 species of odontocete cetaceans have been assessed for potential impacts due to operation of SURTASS LFA sonar. Odontocetes can be distinguished from mysticetes by the presence of functional teeth and a single blowhole. Odontocetes have a broad acoustic range, with recent hearing thresholds measuring between 400 Hz and 100 kHz (Finneran et al., 2002). Many odontocetes produce a variety of click and tonal sounds for communication and echolocation purposes (Au, 1993). Odontocetes communicate mainly above 1,000 Hz and echolocation signals as high as 150 kHz (Würsig and Richardson, 2009). Little is known about the details of most sound production and auditory thresholds for many species (Frankel, 2009).

4.2.1 SPERM WHALE (*PHYSETER MACROCEPHALUS*)

The sperm whale is currently endangered under the ESA, depleted under the MMPA, classified by IUCN as vulnerable, and classified as protected under CITES. The global population of sperm whales is unknown, but is estimated to be about 360,000 (Jefferson et al., 2008). Estimates were 4,000 for the eastern tropical Pacific (ETP), 76,000 for the northern Pacific, 14,000 for the northern Atlantic, and 1,665 for the northern Gulf of Mexico (Jefferson et al., 2008; Waring et al., 2009).

Sperm whales are primarily found in deeper (>1000 m [3,280 ft]) ocean waters and distributed in polar, temperate, and tropical zones of the world (Reeves and Whitehead, 1997). They have the largest range of all cetaceans, except killer whales (Rice, 1989) and commonly occur near the equator and in the North Pacific (Whitehead, 2009). The migration patterns of sperm whales are not well understood, as some whales show seasonal north-south migrational patterns while others show no clear seasonal migration, especially in the equatorial areas (Whitehead, 2009). Males of the eastern North Pacific stock are thought to move north in the summer to feed in the Gulf of Alaska, Bering Sea, and waters around the Aleutian Islands (Kasuya and Miyashita, 1988). Mark-recapture data show extensive movements throughout the North Pacific and along the U.S. west coast into the Gulf of Alaska and Bering Sea/Aleutian Islands region (Allen and Angliss, 2011). The sperm whale has a prolonged breeding season extending from late winter through early summer. In the Southern Hemisphere, the calving season is between November and March (Simmonds and Hutchinson, 1996), although specific breeding and foraging grounds are not well known for this species.

Swim speeds of sperm whales generally range from 2.6 to 4 km/hr (2.2 kts) (Watkins et al., 2002; Whitehead, 2009). Dive durations range between 18.2 to 65.3 min (Watkins et al., 2002). Sperm whales may be the longest and deepest diving mammals with recorded dives to 1,500 m (4,921 ft) (Davis et al, 2007), but stomach content evidence suggests that sperm whales may dive as deep as 3,200 m (10,498 ft) (Clarke, 1976). Foraging dives typically last about 30 to 40 min and descend to depths from 300 to 1,245 m (984 to 4,085 ft) (Papastavrou, 1989; Wahlberg, 2002).

Recent audiograms measured from a sperm whale calf suggest an auditory range of 2.5 to 60 kHz, with best hearing sensitivity between 5 and 20 kHz (Ridgway and Carder, 2001). Measurements of evoked response data from one stranded sperm whale have shown a lower limit of hearing near 100 Hz (Gordon et al., 1996).

Sperm whales produce broadband clicks with energy from less than 100 Hz to 30 kHz (Watkins and Schevill, 1977; Watkins et al., 1985; Goold and Jones, 1995; Weilgart and Whitehead, 1997; Mohl et al., 2000; Madsen et al., 2002; Thode et al., 2002). Regular click trains and creaks have been recorded from foraging sperm whales and may be produced as a function of echolocation (Whitehead and Weilgart, 1991; Jaquet et al., 2001; Madsen et al., 2002). A series of short clicks, termed “codas,” have been associated with social interactions and are thought to play a role in communication (Watkins and Schevill, 1977; Weilgart and Whitehead, 1993; Pavan et al., 2000). Distinctive coda repertoires have shown evidence of geographical variation among female sperm whales (Weilgart and Whitehead, 1997; Whitehead, 2009). SELs of clicks have been measured between 202 and 236 dB (Mohl et al., 2000; Mohl et al., 2003; Madsen, 2000; Thode et al., 2002). Mohl et al. (2000) reported results from recordings of sperm whales at high latitudes with a large-aperture array that were interpreted to show high directionality in their clicks, with maximum recorded SLs greater than 220 dB. Mohl et al. (2003) further described the directionality of the clicks and show that the source levels of clicks differ significantly with aspect angle. This is dependent on the direction that the click is projected and the point where the click is received. The maximum SL for any click in these recordings was 236 dB with other independent events ranging from 226 to 234 dB (Mohl et al., 2003).

Zimmer et al. (2005) discuss the three-dimensional beam pattern of regular sperm whale clicks. Regular clicks have several components including a narrow, high-frequency sonar beam to search for prey, a less-directional backward pulse that provides orientation cues, and a low-frequency component of low directionality that conveys sound to a large part of the surrounding water column with a potential for reception by conspecifics at large ranges. The click travel time was used to estimate the acoustic range of the whale during its dives. In this study, the SL of the high-frequency sonar beam in the click was 229 dB (peak value). The backward pulse had an SL of 200 dB (peak value). The low-frequency component immediately followed the backward pulse and had a long duration, with peak frequencies that are depth dependent to over 500 m (1640 ft). Zimmer et al. (2005) propose that the initial backward pulse is produced by the phonic lips and activates air volumes connected to the phonic lips, which generate the low-frequency component. The two dominant frequencies in the low-frequency component indicate either one resonator with aspect-dependent radiation patterns or two resonators with similar volumes at the surface but different volumes at various depths. Most of the energy of the initial backward-directed pulse reflects forward off the frontal sac into the junk and leaves the junk as a narrow, forward-directed pulse. A fraction of that energy is reflected by the frontal sac back into the spermaceti organ to generate higher-order pulses. This forward-directed pulse is well suited for echolocation.

4.2.2 PYGMY SPERM WHALE *(KOGIA BREVICEPS)* AND DWARF SPERM WHALE *(KOGIA SIMA)*

Both the pygmy sperm whale and dwarf sperm whale are listed as data deficient under the IUCN. These species are not listed as threatened or endangered under the ESA nor are they categorized as depleted under the MMPA. Abundance estimates of the global population sizes for these species are unknown. However, there are estimates for specific geographic regions. Jefferson et al. (2008) stated that there are an estimated 3,000 pygmy sperm whales off the coast of California, and an estimated 11,000 dwarf sperm whales in the ETP. In the Atlantic, there is an estimated 395 pygmy and dwarf sperm whales, and 453 in the Gulf of Mexico (Waring et al., 2009). Pygmy and dwarf sperm whales are distributed worldwide, primarily in temperate to tropical deep waters. They are especially common along continental shelf breaks (Evans, 1987); Jefferson et al., 2008). Dwarf sperm whales seem to prefer warmer water than the pygmy sperm whale (Caldwell and Caldwell, 1989). Breeding areas for both species include waters off Florida (Evans, 1987). There is little evidence that pygmy and dwarf sperm whales have a seasonal migration pattern (McAlpine, 2009).

Swim speeds vary and were found to reach up to 11 km/hr (5.9 kts) (Scott et al., 2001). In the Gulf of California, *Kogia* spp. have been recorded with an average dive time of 8.6 min, whereas dwarf sperm whales in the Gulf of Mexico exhibited a maximum dive time of 43 min (Breese and Tershy, 1993; Willis and Baird, 1998).

There are sparse data on the hearing sensitivity for pygmy sperm whales. An ABR study on a rehabilitating pygmy sperm whale indicated that this species has an underwater hearing range that is most sensitive between 90 and 150 kHz (Carder et al., 1995; Ridgway and Carder, 2001). No hearing measured hearing data are available for the dwarf sperm whale. Recent recordings from captive pygmy sperm whales indicate that they produce sounds between 60 and 200 kHz with peak frequencies at 120 to 130 kHz (Santoro et al., 1989; Carder et al., 1995; Ridgway and Carder, 2001). Echolocation pulses were documented with peak frequencies at 125 to 130 kHz (Ridgway and Carder, 2001). Thomas et al. (1990) recorded an LF swept signal between 1.3 to 1.5 kHz from a captive pygmy sperm whale in Hawaii. Jérémie et al. (2006) reported frequencies ranging from 13 to 33 kHz for dwarf sperm whale clicks with durations of 0.3 to 0.5 sec. No geographical or seasonal differences in sounds have been documented. Estimated source levels were not available.

4.2.3 BAIRD'S BEAKED WHALE *(BERARDIUS BAIRDII)* AND ARNOUX'S BEAKED WHALE *(BERARDIUS ARNUXII)*

Both the Baird's and Arnoux's beaked whales are currently classified as data deficient under the IUCN. These species are not listed as threatened or endangered under the ESA nor are they categorized as depleted under the MMPA. Abundance estimates of the global population size for either species are unknown. The abundance of both species has been estimated as 5,029 whales off the Pacific coast of Japan, 1,260 whales in the eastern Sea of Japan, and 660 in the southern Sea of Okhotsk (Kasuya, 2009). Baird's beaked whale population numbers are estimated as 1,100 in the eastern North Pacific, including 540 Baird's beaked whales in the waters of Washington, Oregon, and California (Jefferson et al., 2008; Caretta et al., 2009).

Baird's beaked whales occur in the North Pacific, including the Bering and Okhotsk seas (Kasuya, 1986 and 2009). Male Baird's beaked whales live to about 84 years old while females live to about 54 years (Kasuya, 2009). Arnoux's beaked whales are distributed in waters surrounding Antarctica, northern New Zealand, South Africa, and southeast Australian. Both species inhabit deep water and appear to be most abundant at areas of steep topographic relief such as shelf breaks and seamounts (Dohl et al., 1983; Kasuya, 1986; Leatherwood et al., 1988). Baird's beaked whales were documented as having an inshore-offshore movement off California beginning in July and ending in September to October (Dohl et al., 1983). Ohizumi et al. (2003) reported that Baird's beaked whales migrate to the coastal waters of the western North Pacific and the southern Sea of Okhotsk in the summer. No data are available to confirm seasonal migration patterns for Arnoux's beaked whales, and no data are available for breeding and calving grounds of either species.

Few swim speed data are available for any beaked whale species. Baird's beaked whales were recorded diving between 15 and 20 min, with a maximum dive duration of 67 min (Barlow, 1999; Kasuya, 2009). In a recent study, a Baird's beaked whale in the western North Pacific had a maximum dive time of 64.4 min and a maximum depth of 1,777 m (5,830 ft). It was also found that one deep dive (>1,000 m [3,280 ft]) was followed by several intermediate dives (100 to 1,000 m [328 to 3,280 ft]) (Minamikawa et al., 2007). Arnoux's beaked whales have a dive time ranging from 10 to 65 min and a maximum of 70 min when diving from narrow cracks or leads in sea ice near the Antarctic Peninsula (Hobson and Martin, 1996). No dive depths are available for Arnoux's beaked whale.

There is no direct measurement of auditory threshold for the hearing sensitivity of either Baird's or Arnoux's beaked whales (Ketten, 2000; Thewissen, 2002). Baird's beaked whales have been recorded producing HF sounds between 12 and 134 kHz with dominant frequencies between 23 to 24.6 kHz and 35 to 45 kHz (Dawson et al., 1998). Arnoux's beaked whales were recorded off Kemp Land, Antarctica, producing sounds between 1 and 8.7 kHz (Rogers, 1999). Both species produced a variety of sounds, mainly burst-pulse clicks and FM whistles. The functions of these signal types are unknown. Clicks and click trains were heard sporadically throughout the recorded data, which may suggest that these beaked whales possess echolocation abilities. There is no available data regarding seasonal or geographical variation in the sound production of these species. Estimated SLs are not documented.

4.2.4 SHEPHERD'S BEAKED WHALE (*TASMACETUS SHEPHERDI*)

The Shepherd's beaked whale is currently classified as a data deficient species by IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. Abundance estimates of this species are not available. Shepherd's beaked whales are distributed in cold temperate to polar seas of the Southern Hemisphere including the waters of Antarctica. Brazil, Galapagos Islands, New Zealand, Argentina, Australia, and the south Sandwich Islands (Mead, 2009b), as well as Tristan de Cunha (Best *et al.*, 2009). No data are available to confirm seasonal migration patterns for Shepherd's beaked whales, and there are no known breeding or calving grounds.

No data are available on swim speeds, dive times, or dive depths for Shepherd's beaked whales. There is no direct measurement of auditory threshold for the hearing sensitivity of Shepherd's beaked whales (Ketten, 2000; Thewissen, 2002). No data are available on sound production for this species.

4.2.5 CUVIER'S BEAKED WHALE (*ZIPHIUS CAVIROSTRIS*)

Cuvier's beaked whale is currently classified as a least concern (lower risk) species by the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. Global population estimates for this species are unknown. Abundances of Cuvier's beaked whales are estimated for the ETP as 20,000 individuals while 90,000 whales are estimated in the eastern North Pacific (Barlow, 1995). Off the U.S. West Coast (CA/OR/WA), 2,830 Cuvier's have been estimated to occur while 12,728 individuals are estimated for Hawaiian EEZ waters (Caretta et al., 2009). The best abundance estimate for pooled beaked whales in the western North Atlantic is 3,513 individuals while 65 Cuvier's are estimated in the northern Gulf of Mexico (Waring et al., 2009).

Cuvier's beaked whales are widely distributed in oceanic tropical to polar waters of all oceans except the high polar areas (Heyning and Mead, 2009). This species is also found in enclosed seas such as Gulf of Mexico, Gulf of California, Caribbean Sea, Mediterranean Sea, Sea of Japan, and the Sea of Okhotsk (Omura et al., 1955; Jefferson et al., 2008). The Cuvier's beaked whale is the most cosmopolitan of all beaked whale species. The Cuvier's apparently prefers waters over the continental slope. Stomach contents contain species from open ocean, meso-pelagic or deep water benthic areas (Heyning and Mead, 2009). No data on breeding and calving grounds are available.

Swim speeds of Cuvier's beaked whale have been recorded between 5 and 6 km/hr (2.7 and 3.3 kts) (Houston, 1991). Dive durations range between 20 and 87 min with an average dive time near 30 min (Heyning, 1989; Jefferson et al., 1993; Baird et al., 2004). This species is a deep diving species and can reach depths of 1,888 m (6,194 ft) (Heyning and Mead, 2009).

There is no direct measurement of auditory threshold for the hearing sensitivity of Cuvier's beaked whales (Ketten, 2000; Thewissen, 2002). Cuvier's beaked whales were recorded producing HF clicks between 13 and 17 kHz; since these sounds were recorded during diving activity, the clicks were assumed to be associated with echolocation (Frantzis et al., 2002). A more recent study on Cuvier's beaked whale vocalization abilities by Johnson et al. (2004) recorded frequencies of Cuvier's clicks ranging from about 12 to 40 kHz with associated SLs of 200 to 220 dB re 1 µPa @ 1 m (peak-to-peak) (Johnson et al., 2004). Johnson et al. (2004) also found that Cuvier's beaked whales do not vocalize when within 200 m (656 ft) of the surface and only started clicking at an average depth of 475 m (1,558 ft) and stopped clicking on the ascent at an average depth of 850 m (2,789 ft) with click intervals of approximately 0.4 seconds. Zimmer et al. (2005a) also studied the echolocation clicks of Cuvier's beaked whales and recorded a SL of 214 dB re 1 µPa @ 1 m (peak-to-peak). There are no available data regarding seasonal or geographical variation in the sound production of Cuvier's beaked whales.

4.2.6 NORTHERN BOTTLENOSE WHALE *(HYPEROODON AMPULLATUS)* AND SOUTHERN BOTTLENOSE WHALE *(HYPEROODON PLANIFRONS)*

The IUCN classifies the status of northern bottlenose whales as data deficient while southern bottlenose whales are currently classified as least concern (lower risk). These species are not listed as threatened or endangered under the ESA nor are they categorized as depleted under the MMPA. Both species are also protected under CITES. Abundance estimates of the global populations are unknown. There are an estimated 40,000 northern bottlenose whales in the North Atlantic Ocean, including the Gully, the region southeast of Sable Island, Nova Scotia with an estimated 130 whales, and the Faroe Islands, with over 5,000 northern bottlenose whales estimated (Whitehead et al., 1997). The Scotian Shelf population of northern bottlenose whales was listed as endangered under Canada's Species at Risk Act (SARA). There are an estimated 500,000 southern bottlenose whales south of the Antarctic Convergence, making them the most common beaked whale sighted in Antarctic waters (Jefferson et al., 2008).

The northern bottlenose whale is found only in the cold temperate to subarctic waters of the North Atlantic from New England to southern Greenland and the Strait of Gibraltar to Svalbard (Jefferson et al., 2008). This oceanic species occurs seaward of the continental shelf in waters deeper than 500 m (1,640 ft) (Leatherwood and Reeves, 1983; Jefferson et al., 2008). Northern bottlenose whales are commonly found foraging in the Gully, off the coast of Nova Scotia, Canada (Gowans, 2009). The Scotian Shelf population appears to be nonmigratory, unlike other northern bottlenose whale populations. The Scotian shelf population appears to be highly, but not completely genetically isolated from the neighboring Labrador population. Genetic studies estimate two individuals per generation move between these populations (Dalebout *et al.*, 2006). The Labrador population migrates to the southern portion of their range, between New York and the Mediterranean, for the winter months. Calving and breeding grounds are unknown for migratory populations.

Southern bottlenose whales are found south of 20°S, with a circumpolar distribution (Leatherwood and Reeves, 1983; Jefferson et al., 2008). Evidence of seasonal migration shows a northward movement near South Africa in February and southward movement toward the Antarctic in October (Sekiguchi et al., 1993). Calving and breeding grounds are unknown.

General swim speeds for ziphiids average 5 km/hr (2.7 kts) (Kastelein and Gerrits, 1991). Hooker and Baird (1999) documented northern bottlenose whales with regular dives from 120 m (394 ft) to over 800 m (2,625 ft), with a maximum recorded dive depth to 1,453 m (4,770 ft). Dive durations have been recorded close to 70 min. Southern bottlenose whales have been observed diving from 11 to 46 min, with an average duration of 25.3 min (Sekiguchi et al., 1993). Bottlenose whales feed primarily on squid (Gowans, 2009), and the deeper dives of northern bottlenose whales have been associated with foraging behavior (Hooker and Baird, 1999).

There is no direct measurement of hearing sensitivity for bottlenose whales (Ketten, 2000; Thewissen, 2002). Off Nova Scotia, diving northern bottlenose whales produced regular click series (consistent inter-click intervals) at depth with peak frequencies of 6 to 8 kHz and 16 to 20 kHz (Hooker and Whitehead, 1998). Click trains produced during social interactions at the surface ranged in peak intensity from 2 to 4 kHz and 10 to 12 kHz. There is no seasonal or geographical variation documented for the northern bottlenose whale. There are no available data for the sound production of southern bottlenose whales.

4.2.7 LONGMAN'S BEAKED WHALE (*INDOPACETUS PACIFICUS*)

Longman's beaked whale, also known as the Indo-Pacific beaked whale, is currently classified as data deficient by IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. Global abundance estimates of this species are not available but 760 animals have been estimated in Hawaiian waters (Jefferson et al., 2008).

The distribution of Longman's beaked whale is limited to the Indo-Pacific region (Leatherwood and Reeves, 1983; Jefferson et al., 2008). Recent whale groups sighted in the equatorial Indian and Pacific Oceans off Mexico and Africa have tentatively been identified as Longman's beaked whales (Ballance and Pitman, 1998; Pitman et al., 1998; Pitman, 2009a). One stranding has been reported in Japan. The stomach contents of this animal contained only squid prey. The distribution of the prey species suggests that Longman's beaked whale feeds in the epipelagic and mesopelagic zones in the western Pacific Ocean (Yatabe *et al.*, 2010). No data are available to confirm seasonal migration patterns for Longman's beaked whales. No data on breeding and calving grounds are available.

No data are available on swim speeds or dive depths. Only a small number of dive times have been recorded from this species. Dive duration in the Longman's beaked whale is 11 to 33 min, possibly up to 45 min (Pitman, 2009a). There is no direct measurement of hearing sensitivity for Longman's beaked whales (Ketten, 2000; Thewissen, 2002). No data are available on sound production in this species.

4.2.8 *MESOPLODON* SPECIES

Species in the genus *Mesoplodon* are currently classified with a data deficient status by IUCN. These species are not listed as threatened or endangered under the ESA nor are they categorized as depleted under the MMPA. The worldwide population sizes for all species of *Mesoplodon* spp. are unknown. However, estimates of 25,300 in the ETP and 250 *Mesoplodon* whales off California have been documented (Wade and Gerrodette, 1993; Barlow, 1995). In addition, minimum population estimates for undifferentiated beaked whales in the western North Atlantic was 3,531 whales (Waring et al, 2009), and an estimate of 1,024 whales was reported in the eastern North Pacific (Carretta et al., 2009).

Mesoplodon whales are distributed in all of the world's oceans except for the cold waters of the Arctic and Antarctic. They are normally found in deep (>2,000 m [6,562 ft]) pelagic water or in continental slope waters (Davis et al., 1998). Sowerby's and True's beaked whales are found in the temperate waters of the North Atlantic, and True's is also found in the southern Indian Ocean. Hector's beaked whales, Gray's beaked whales, and Andrew's beaked whales are found in the temperate waters of the Southern Hemisphere. Gervais' beaked whale is found in warm, temperate, and tropical waters of the North Atlantic. Pygmy beaked whales and ginkgo-toothed beaked whales are found in tropical warm waters in the Pacific, and the ginkgo-toothed beaked whale is also found in the tropical waters of the Indian Ocean. Stejneger's beaked whale and Hubb's beaked whale are found in the temperate North Pacific, and the Stejneger's beaked whale can also be found in subarctic waters. Blainville's beaked whales are the most cosmopolitan of the beaked whales and can be found in the Atlantic, Pacific, and Indian oceans in warm temperate and tropical waters (Pitman, 2009b).

Mesoplodon whales feed primarily on squid and fish, although a few crustaceans have been found in stomach contents (MacLeod et al., 2003). Some species may rely more on fish than squid. In fact the paucity of data on stomach contents may be an artifact of the faster digestion rate of fish (MacLeod et al., 2003).

While there are indications of relatively large scale movement of individual beaked whales (Claridge, 2006). Blainsville's beaked whales tagged in Hawai'i made total movement of up to 2923 km (1578 nmi), yet the net distance from the tagging location never exceeded 139 km (75 nmi) (Schorr et al., 2009).

Few swim speed data are available for any beaked whale species. Schorr et al. (2009) reported a horizontal swim speed of 0.8 to 1.5 km/hr (0.4 to 0.8 kts) for a Blainville's beaked whales in Hawaii with a maximum rate of 8.1 km/hr. Dives of Blainville's beaked whales average 7.5 min during social interactions at the surface (Baird et al., 2004). Dives over 45 min have been recorded for some species in this genus (Jefferson et al., 1993). Dive depths are variable among species and not well documented. In Hawaii, a Blainville's beaked whale had a maximum dive depth of 1,408 m (4,619 ft), and dive duration from 48 to 68 min (Pitman, 2009b).

Hubb's beaked whale has been recorded producing whistles between 2.6 and 10.7 kHz, and pulsed sounds from 300 Hz to 80 kHz and higher with dominant frequencies from 300 Hz to 2 kHz (Buerki et al., 1989; Lynn and Reiss, 1992). A stranded Gervais' beaked whale had an upper limit for effective hearing at 80 to 90 kHz (Finneran et al., 2009). An audiogram measured from a stranded Blainsville's beaked whale includes hearing threshold from 5.6 to 160 kHz. The best hearing range spanned 40-50 kHz, with threshold below 50 dB re 1μPa (Pacini et al., 2011).

In a study of echolocation clicks in Blainville's beaked whales, Johnson et al. (2006) found that the whales make various types of clicks while foraging. The whales have a distinct search click that is in the form of an FM upsweep with a minus 10 dB bandwidth from 26 to 51 kHz (Johnson et al., 2006). They also produce a buzz click that is during the final stage of prey capture, and they have no FM structure with a minus 10 dB bandwidth from 25 to 80 kHz or higher (Johnson et al., 2006).

Studies on Cuvier's beaked whales and Blainville's beaked whales conducted by Johnson et al. (2004) concluded that no vocalizations were detected from any tagged beaked whales when they were within 200 m (656 ft) of the surface. The Blainville's beaked whale started clicking at an average depth of 400 m (1,312 ft), ranging from 200 to 570 m (656 to 1,870 ft), and stopped clicking when they started their ascent at an average depth of 720 m (2,362 ft), with a range of 500 to 790 m (1,640 to 2,591 ft). The intervals between regular clicks were approximately 0.4 second. Trains of clicks often end in a buzz. Both the Cuvier's beaked whale and the Blainville's beaked whale have a somewhat flat spectrum that was accurately sampled between 30 and 48 kHz. There may be a slight decrease in the spectrum above 40 kHz, but the 96 kHz sampling rate was not sufficient to sample the full frequency range of clicks from either of the species (Johnson et al., 2004). Gervais' beaked whales produced echolocation signals between 30 and 50 kHz, slightly higher in frequency than Blainsville's and Cuvier's beaked whale (Gillespie et al., 2009).

4.2.9 BELUGA WHALE (*DELPHINAPTERUS LEUCAS*)

The beluga is classified as a near threatened species by the IUCN, and the Cook Inlet stock is a listed as endangered under the ESA (Jefferson et al., 2008; NMFS, 2008) and depleted under the MMPA. The remaining four stocks, the eastern Bering, Eastern Chukchi, Beaufort, and Bristol Bay, are not considered depleted under the MMPA nor are listed under the ESA. Worldwide abundance is estimated near 150,000, with 39,258 in the Beaufort Sea, 3,710 in the eastern Chukchi Sea, 7,986 in the eastern Bering Sea, 18,142 in Norton Sound, 2,877 in Bristol Bay, 375 in Cook Inlet, 28,000 in Baffin Bay, 25,000 in western Hudson Bay, 10,000 in eastern Canada, and over 21,000 in Russian waters, including the Sea of Okhotsk (Jefferson et al., 2008; Angliss and Allen, 2009). Critical habitat is designated in Cook Inlet, Alaska, for the Cook Inlet belugas (NOAA, 2011).

Beluga habitat is found in both shallow and deep water of the north circumpolar region ranging into the subarctic. Belugas inhabit the east and west coasts of Greenland, and their distribution in North America extends from Alaska across the Canadian western arctic to the Hudson Bay (Jefferson et al., 2008). Occasional sightings and strandings occur as far south as the Bay of Fundy in the Atlantic. Belugas tend to summer in large groups in bays, shallow inlets, and estuaries. Possible reasons include warmer water in the shallow areas, and availability of anadromous fish, such as salmon, capelin, and smelt which are highly abundant in those areas during the summer months (O'Corry-Crowe, 2009). In the Pacific, migratory belugas summer in the Okhotsk, Chukchi, Bering, and Beaufort seas, the Anadyr Gulf, and waters off Alaska (Jefferson et al., 2008; Waring et al., 2009). Other beluga populations reside in Cook Inlet year round (Hansen and Hubbard, 1999). Little is known about beluga whales in the winter, but it is believed that the whales migrate in the direction of the advancing ice front, and overwinter near holes in the ice called "polynyas" (O'Corry-Crowe, 2009).

Little is known of the mating behavior of belugas, although mating is believed to be concentrated in late winter to early spring, the time of year when it is hardest to study this species (O'Corry-Crowe, 2009). Gestation lasts approximately 14 months and mothers typically nurse for two years. The maximum age of belugas remains somewhat in doubt, as the issue of the rate of deposition of growth layer groups (GLGs) remains unsettled. Analysis of atomic bomb radiocarbon indicates annual deposition (Stewart et al., 2006). While annual deposition, which would indicate a life span of 60 years seems most likely, a working group was unable to unequivocally settle this issue (Lockyer et al., 2007).

The beluga is not a fast swimmer, with maximum swim speeds estimated between 16 and 22 km/hr (8.6 and 11.9 kts) and a steady swim rate in the range of 2.5 to 3.3 km/hr (1.3 to 1.8 kts) (Brodie, 1989; O’Corry-Crowe, 2009). Studies on diving capabilities of trained belugas in open ocean conditions by Ridgway et al. (1984) demonstrated a capacity to dive to depths of 647 m (2,123 ft) and remain submerged for up to 15 min. Most dives fall into either of two categories: shallow surface dives or deep dives. Shallow dive durations of belugas are less than 1 min. Deep dives last for 9 to 18 min, and dive depths range between 300 and 600 m (984 and 1,968 ft). In deep waters beyond the continental shelf, belugas may dive in excess of 1,000 m (3,281 ft), remaining submerged for up to 25 min (O’Corry-Crowe, 2009).

Belugas have hearing thresholds approaching 42 dB RL at their most sensitive frequencies (11 to 100 kHz) with overall hearing sensitivity from 40 Hz to 150 kHz (Awbrey et al., 1988; Johnson et al., 1989; Au, 1993; Ridgway et al., 2001). Awbrey et al. (1988) measured hearing thresholds for three captive belugas between 125 Hz and 8 kHz. They found that the average threshold was 65 dB RL at 8 kHz. Below 8 kHz, sensitivity decreased at approximately 11 dB per octave and was 120 dB RL at 125 Hz. A study by Mooney et al. (2008) found that belugas had a more sensitive hearing threshold than previously thought. The studied whale had a hearing threshold below 60 dB re 1 µPa between 32 and 80 kHz and below 70 db at 11.2 and 90 kHz (Mooney et al., 2008).

Belugas produce tonal calls or whistles in the 260 Hz to 20 kHz range and a variety of call types in the 100 Hz to 16 kHz range. Echolocation clicks extend to 120 kHz (Schevill and Lawrence, 1949; Sjare and Smith 1986; O'Corry-Crowe, 2009). There are 50 different call types, including “groans,” “whistles,” “buzzes,” “trills” and “roars” (O'Corry-Crowe, 2009). Beluga whales are commonly most vocal during milling and social interactions (Karlsen et al., 2002). Predominant echolocation frequencies are bimodal for this species and occur in ranges of 40 to 60 kHz and 100 to 120 kHz at SLs between 206 and 225 dB (Au, 1993; Au et al., 1987). There is supportive evidence of geographical variation from distinctive calls used for individual recognition among beluga whales (Belkovich and Shekotov, 1990).

4.2.10 KILLER WHALE (*ORCINUS ORCA*)

The killer whale is classified as a data deficient species under the IUCN. On 18 November 2005, the NMFS published a final determination to list the Southern Resident killer whales (*Orcinus orca*) distinct population segment (DPS) as endangered under the ESA, which was effective in 2005 (NOAA, 2005). Both the Southern Resident and AT 1 stocks of killer whales are classified as depleted under the MMPA. Critical habitat is designated for the Southern Resident killer whales in the inland marine waters of Washington (Puget Sound, Strait of Juan de Fuca, and Haro Strait) (NOAA, 2006).

Although no current global population estimates are available, Reeves and Leatherwood (1994) estimated the killer whale worldwide abundance near 100,000 individuals. An abundance of 8,500 killer whales was estimated for the waters of the ETP, while 445 and nearly 80,000 killer whales are estimated for northern Norwegian waters and south of the Antarctic Convergence Zone, respectively (Wade and Gerrodette, 1993; Jefferson et al., 2008). In U.S. Atlantic waters, 49 killer whales are estimated to occur in the northern Gulf of Mexico but no abundance could be estimated for the western north Atlantic stock (Waring et al., 2009). In the Eastern North Pacific killer whale stock, as many as 353 Offshore, 86 Southern Resident, 1,123 Alaska Resident, 216 Northern Resident, 249 Alaska Transient, 7 AT1 Transient, and 314 West Coast Transient killer whales have been estimated in these sub-stocks (Angliss and Allen, 2009; Carretta et al., 2009). About 430 killer whales currently are estimated in the Hawaiian stock (Carretta et al., 2009). Resident killer whales occur in large pods with roughly 10 to 60 members. Resident killer whales in the North Pacific consist of the southern, northern, southern Alaska (which includes southeast Alaska and Prince William Sound whales), western Alaska, and western North Pacific groups (NOAA, 2005).

The killer whale is perhaps the most cosmopolitan of all marine mammals, found in all the world's oceans from about 80°N to 77°S, especially in areas of high productivity and in high latitude coastal areas (Leatherwood and Dahlheim, 1978; Ford, 2009). However, they appear to be more common within 800 km (430 nmi) of major continents in cold-temperate to subpolar waters (Mitchell, 1975).

Killer whales are found in at least three different ecotypes; resident, transients and offshore animals are found in the northern hemisphere (Olesiuk et al., 2005), with three ecotypes (A, B and C) found in Antarctic waters (Ford, 2009). The different eco-type specialize on different types of prey, typically fish (e.g. residents) and/or marine mammals (e.g. transients). In some cases their specialization can be quite narrow. The Pacific Northwest resident killer whales appear to specialize on Chinook salmon, even though other salmonids are more numerous, making their population directly dependent on the health of one prey species population (Ford et al., 2010). At least some North Atlantic killer whale populations appear to have a broader foraging niche, typically predating on both marine mammals and fish (Foote et al., 2010). In the Antarctic, Type A whales appear to specialize on minke whales, Type B preys primarily on seals, and Type C has only been observed to eat Antarctic toothfish (Pitman and Ensor, 2003).

Reproduction within the southern resident ecotype appears to occur frequently within each pod, but not with closely related individuals (Ford et al., 2011). Furthermore, there was no evidence of the southern resident whales mating with other groups. However, it is unknown how similar the different ecotypes are to the southern resident group. In the northern resident group, females typically birth to their first calf at about ages 12-14 and produce an average of five calves over their reproduction lifespan (Ford, 2009). Approximately half of the females become reproductively senescent by age 41, and the oldest known mother was 44. Calving is believed to peak in autumn, but may occur during any season (Olesiuk et al., 2005).

Most females survive to the mean age of reproductive senescence, at which time female mortality appears to increase. Individual females are thought to live to at least 100 years old. Male mortality follows a more typical mammalian pattern, with high mortality rates for very young and very old males (Olesiuk et al., 2005).

Swimming speeds usually range between 6 to 10 km/hr (3.2 to 5.4 kts), but they can achieve speeds up to 37 km/hr (20 kts) in short bursts (Lang, 1966; LeDuc, 2009). In southern British Columbia and northwestern Washington State, killer whales spend 70% of their time in the upper 20 m (66 ft) of the water column, but can dive to 100 m (330 ft) or more with a maximum recorded depth of 201 m (660 ft) (Baird et al., 1998). The deepest dive recorded by a killer whale is 265 m (870 ft), reached by a trained individual (Ridgway, 1986). Dive durations range from 1 to 10 min (Norris and Prescott, 1961; Lenfant, 1969; Baird et al., 1998).

Killer whales hear underwater sounds in the range of <500 Hz to 120 kHz (Bain et al., 1993; Szymanski et al., 1999). Their best underwater hearing occurs between 15 and 42 kHz, where the threshold level is near 34 to 36 dB RL (Hall and Johnson, 1972; Szymanski et al., 1999). Killer whales produce sounds as low as 80 Hz and as high as 85 kHz with dominant frequencies at 1 to 20 kHz (Schevill and Watkins, 1966; Diercks et al., 1971, 1973; Evans, 1973; Steiner et al., 1979; Awbrey et al., 1982; Ford and Fisher, 1982; Ford, 1989; Miller and Bain, 2000). An average of 12 different call types (range 7 to 17)—mostly repetitive discrete calls—exist for each pod (Ford, 2009). Pulsed calls and whistles, called dialects, carry information hypothesized as geographic origin, individual identity, pod membership, and activity level. Vocalizations tend to be in the range between 500 Hz and 10 kHz and may be used for group cohesion and identity (Ford, 2009; Frankel, 2009). Whistles and echolocation clicks are also included in killer whale repertoires, but are not a dominant signal type of the vocal repertoire in comparison to pulsed calls (Miller and Bain, 2000). Erbe (2002) recorded received broadband sound pressure levels of orca burst-pulse calls ranging between 105 and 124 dB RL at an estimated distance of 100 m (328 ft).

4.2.11 FALSE KILLER WHALE (*PSEUDORCA CRASSIDENS*)

False killer whales are classified as least concern (lower risk) by the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. The global population for this species is unknown. Estimates of 39,800 have been documented in the ETP (Wade and Gerrodette, 1993). In the northwestern Pacific, an estimate of near 17,000 has been documented (Miyashita, 1993). In the Gulf of Mexico, there is an estimated 777 false killer whales (Waring et al., 2009).

False killer whales are found in tropical to warm temperate zones in deep, offshore waters (Stacey et al., 1994; Odell and McClune, 1999; Baird, 2009a). Although typically a pelagic species, they approach close to the shores of oceanic islands and regularly mass strand (Baird, 2009a). False killer whales have a poorly known ecology. Breeding grounds and seasonality in breeding are unknown; however, one population does have a breeding peak in late winter (Jefferson et al., 2008). Adults of both sexes are thought to become sexually mature between ages of 8 and 14. Males may mature later than females. Maximum life span has been estimated at 57 for males and 62 for females (Baird, 2009a; Yoshida *et al.*, 2010). These whales do not have specific feeding grounds but feed opportunistically on squid, large fish and marine mammals (Jefferson et al., 2008; (Odell and McClune, 1999). False killer whales have an approximate swim speed of 3 km/hr (1.6 kts), although a maximum swim speed has been documented at 28.8 km/hr (11.9 kts) (Brown et al. 1966; Rohr et al., 2002).

False killer whales hear underwater sounds in the range of less than 1 to 115 kHz (Johnson, 1967; Au, 1993). Their best underwater hearing occurs at 17 kHz, where the threshold level ranges between 39 to 49 dB RL. In a study by Yuen et al. (2005), false killer whales' hearing was measured using both behavioral and AEP audiograms. The behavioral data show that this species is most sensitive between 16 and 24 kHz, with peak sensitivity at 20 kHz. The AEP data shows that this species best hearing sensitivity is from 16 to 22.5 kHz, with peak sensitivity at 22.5 kHz. Au et al. (1997) studied the effects of the Acoustic Thermometry of Ocean Climate (ATOC) program on false killer whales. The ATOC source transmitted 75-Hz, 195 dB SL signals. The hearing thresholds for false killer whales were 140.7 dB RL $\pm$ 1.2 dB for the 75-Hz pure tone and 139.0 dB RL $\pm$ 1.1 dB for the ATOC signal.

False killer whales produce a wide variety of sounds from 4 to 130 kHz, with dominant frequencies between 25 to 30 kHz and 95 to 130 kHz (Busnel and Dziedzic, 1968; Kamminga and van Velden, 1987; Thomas and Turl, 1990; Murray et al., 1998). Most signal types vary among whistles, burst-pulse sounds and click trains (Murray et al. 1998). Whistles generally range between 4.7 and 6.1 kHz. False killer whales echolocate highly directional clicks ranging between 20 and 60 kHz and 100 and 130 kHz (Kamminga and van Velden, 1987; Thomas and Turl, 1990). There are no available data regarding seasonal or geographical variation in the sound production of false killer whales. Estimated SL of clicks are near 228 dB (Thomas and Turl, 1990).

4.2.12 PYGMY KILLER WHALE (*FERESA ATTENUATA*)

Pygmy killer whales are one of the least known cetacean species. This species is not listed as threatened or endangered under the ESA, nor is it categorized as depleted under the MMPA, but it is classified as data deficient by the IUCN. The global population for this species is unknown. Estimates of 39,000 have been documented in the ETP (Jefferson et al., 2008). An estimated 323 pygmy killer whales were reported in the Gulf of Mexico (Waring et al., 2009).

Pygmy killer whales have been recorded in oceanic tropical and subtropical waters (Caldwell and Caldwell, 1971; Donahue and Perryman, 2009). It is sighted relatively frequently in the ETP, the Hawaiian archipelago and off Japan (Leatherwood et al., 1988; Donahue and Perryman, 2009). Pygmy killer whales forage on a wide variety of prey species, including fish, squid and apparently small delphinids (Ross, 1994). No data are available to confirm seasonal migration patterns for pygmy killer whales. No data on breeding and calving grounds are available. The smallest known sexually mature female was 2.04 m

(6.70 ft) and the smallest male reported was 2.07 m (6.79 ft) (Mignucci-Giannoni *et al.*, 2000). General swim speeds for this species are not available, and no dive data are available.

Little information is available on the hearing sensitivity of pygmy killer whales. Recently, AEP-derived audiograms were obtained on two live-stranded pygmy killer whales during rehabilitation. The U-shaped audiograms of these pygmy killer whales showed that best hearing sensitivity occurred at 40 kHz with lowest hearing thresholds having occurred between 20 and 60 kHz (Montie et al., 2011). These stranded animals did not hear well at higher frequencies (90 and 96 dB re 1 µPa at 100 kHz) (Montie et al., 2011). Little is known of the sound production of this species. One document describes pygmy killer whales producing LF “growl” sounds (Pryor et al., 1965).

4.2.13 MELON-HEADED WHALE (*PEPONOCEPHALA ELECTRA*)

Melon-headed whales are classified as a lower risk (least concern) species by the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. The global population for this species is unknown. Estimates of 45,000 have been documented in the ETP (Jefferson et al., 2008). An estimate of 2,283 whales was reported for the northern Gulf of Mexico (Waring et al., 2009).

The melon-headed whale occurs in pelagic tropical and subtropical waters (Jefferson and Barros, 1997). Breeding areas and seasonal movements of this species have not been confirmed. Melon-headed whales feed on fish and mesopelagic squid found down to 1,500 m (4,920 ft) deep, so they appear to feed deep in the water column (Jefferson and Barros, 1997). General swim speeds for this species are not available. No data are available on dive depths and dive times of melon-headed whales.

Females appear to reach sexual maturity at age 11.5, with males maturing later, around 15 years old (Perryman, 2009).

There is no direct measurement of hearing sensitivity for melon-headed whales (Ketten, 2000; Thewissen, 2002). Dominant frequencies of whistles range from 1 to 23.5 kHz, with both upsweeps and downsweeps in frequency modulation (Frankel and Yin, 2010). Melon-headed whales produce sounds between 8 and 40 kHz. Individual click bursts have frequency emphases between 20 and 40 kHz. There are no available data regarding seasonal or geographical variation in the sound production of this species. Maximum SLs are estimated at 155 dB for whistles and 165 dB re 1 µPa at 1 m for click bursts (Watkins et al., 1997).

4.2.14 LONG-FINNED PILOT WHALE (*GLOBICEPHALA MELAS*)

This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. The long-finned pilot whale is classified as data deficient by the IUCN. The global population for the long-finned pilot whale is unknown. An estimated 200,000 exist in the Antarctic Convergence (Jefferson et al., 2008). An estimate of 31,139 long-finned pilot whales was reported for the western North Atlantic and 780,000 in the eastern North Atlantic (Jefferson et al., 2008; Waring et al., 2009).

Long-finned pilot whales occur off shelf edges in deep pelagic waters and in temperate and subpolar zones excluding the North Pacific (Nelson and Lien, 1996). There is a high abundance of long-finned pilot whales in the Mediterranean Sea and evidence of an autumn migration near this area (Croll et al., 1999). There is also a seasonal migration evident around Newfoundland that may be correlated to a breeding season lasting from May to November (Sergeant, 1962; Nelson and Lien, 1996).

Long-finned pilot whales feed primarily on squid augmented with some fish species. Long-finned pilot whale females reach sexual maturity at about 8 years old, while males become mature at about 12 years old. In the northern hemisphere, mating typically occurs in spring or early summer with calving occurring in the summer or fall. The reproductive interval is longer than average, with females lactating for up to three year. Males typically live to be 35-45 years old while females can exceed 60 years old (Olson, 2009).

Pilot whales generally have swim speeds ranging between 2 to 12 km/hr (1.1 to 6.5 kts) (Shane, 1995). Long-finned pilot whales have an average speed of 3.3 km/hr (1.8 kts) (Nelson and Lien, 1996) and are considered deep divers (Croll et al., 1999). Dive depths of long-finned pilot whales range from 16 m (52 ft) during the day to 648 m (2,126 ft) during the night (Baird et al., 2002). Dive duration varied between 2 and 13 min.

Although little information is available on the hearing sensitivity of the long-finned pilot whale, a recent study by Pacini et al. (2010) measured the first audiogram of this species. The AEP-derived audiogram of a rehabilitated stranded long-finned pilot whale showed the U-shaped curve common in other mammals. The audiogram results found best hearing between 11.2 and 50 kHz with thresholds below 70 dB, while best hearing sensitivity was found at 40 kHz with a 53.1 dB threshold (Pacini et al., 2010). Pilot whales echolocate with a precision similar to bottlenose dolphins and also vocalize with other school members (Olson, 2009). Long-finned pilot whales produce sounds, including double clicks and whistles, with frequencies as low as 500 Hz and as high as 18 kHz, with dominant frequencies between 3.5 and 5.8 kHz (Schevill, 1964; Busnel and Dziedzic, 1966; Taruski, 1979; Steiner, 1981; McLeod, 1986; Rendell et al., 1999). Sound production of long-finned pilot whales is correlated with behavioral state and environmental context (Taruski, 1979; Weilgart and Whitehead, 1990; Frankel, 2009). For example, signal types described as non-wavering whistles are associated with resting long-finned pilot whales. The whistles become more complex in structure as more social interactions take place (Frankel, 2009). There are no available data regarding seasonal or geographical variation in the sound production of the long-finned pilot whale. Estimated source levels were not available.

4.2.15 SHORT-FINNED PILOT WHALE (*GLOBICEPHALA MACRORHYNCHUS*)

The short-finned pilot whale is classified as data deficient by the IUCN, is not listed as threatened or endangered under the ESA, nor is it categorized as depleted under the MMPA. A global population estimate for short-finned pilot whales is unknown. Off the U.S. west coast, abundance estimates are approximately 1,000 animals (Jefferson et al., 2008). Estimates of 500,000 have been documented in the ETP, 7,700 have been estimated in Philippine waters, and 60,000 in Japanese waters (Jefferson et al., 2008). Estimates of 716 and 31,139 short-finned pilot whales were reported for the Gulf of Mexico and western North Atlantic, respectively (Waring et al., 2009).

Short-finned pilot whales have a tropical and subtropical distribution (Olson, 2009). There appears to be little seasonal movement of this species. Some short-finned pilot whales stay year round near the California Channel Islands whereas others are found offshore most of the year moving inshore with the movement of squid (Croll et al., 1999). Calving season peaks during the spring and fall in the Southern Hemisphere. No breeding grounds have been confirmed.

Short-finned pilot whales feed primarily on squid augmented with some fish species. Long-finned pilot whale females reach sexual maturity at about 9 years old, while males become mature at about 13-16 years old. In the northern hemisphere, mating typically occurs in spring or early summer with calving occurring in the summer or fall. The reproductive interval is longer than average, with females lactating for up to three year. Males typically live to be 35-45 years old while females can exceed 60 years old (Olson, 2009).

Pilot whales generally have swim speeds ranging between 2 to 12 km/hr (1.1 to 6.5 kts) (Shane, 1995). Short-finned pilot whales have swim speeds ranging between 7 and 9 km/hr (3.8 and 4.6 kts) (Norris and Prescott, 1961). Both long- and short-finned pilot whales are considered deep divers, feeding primarily on fish and squid (Croll et al., 1999). A short-finned pilot whale was recorded as diving to 610 m (2,000 ft) (Ridgway, 1986).

No information has been available on short-finned pilot whale hearing until recently. AEPs were used to measure the hearing sensitivity of two short-finned pilot whales (Schlundt et al., 2011). This study tested hearing of one captive and one stranded short-finned pilot whale and found the region of best hearing sensitivity for the captive whale to be between 40 and 56 kHz (thresholds of 78 and 79 dB re 1 µPa, respectively) with the upper limit of functional hearing between 80 and 100 kHz (Schlundt et al., 2011). The only measurable detection threshold for the stranded pilot whale was 108 dB re 1 µPa at 10 kHz, which suggested severe hearing loss above 10 kHz (Schlundt et al., 2011). The hearing range of the captive short-finned pilot whale was similar to other odontocete species, particularly of larger toothed whales. Pilot whales echolocate with a precision similar to bottlenose dolphins and also vocalize with other school members (Olson, 2009). Short-finned pilot whales produce sounds as low as 280 Hz and as high as 100 kHz, with dominant frequencies between 2 to 14 kHz and 30 to 60 kHz (Caldwell and Caldwell, 1969; Fish and Turl, 1976; Scheer et al., 1998). The mean frequency of calls produced by short-finned pilot whales is 7,870 Hz, much higher than the mean frequency of calls produced by long-finned pilot whales (Rendell et al., 1999). Echolocation abilities have been demonstrated during click production (Evans, 1973). SLs of clicks have been measured as high as 180 dB (Fish and Turl, 1976; Richardson et al., 1995). There are little available data regarding seasonal or geographical variation in the sound production of the short-finned pilot whale, although there is evidence of group specific call repertoires (Olson, 2009).

4.2.16 RISSO'S DOLPHIN (*GRAMPUS GRISEUS*)

Risso's dolphins are classified as a least concern (lower risk) species by the IUCN, are not listed as threatened or endangered under the ESA, nor are it categorized as depleted under the MMPA. Although no global population abundance exists for the Risso's dolphin, in the waters of the ETP, Japan, the Philippines, and off Sri Lanka abundances have been estimated at 175,000; 83,000; 950; and 5,550 to 13,000 dolphins, respectively (Jefferson et al., 2008). In the U.S. Pacific Ocean waters, an estimated 11,621 Risso's dolphins occur in the California/Oregon/Washington stock while 2,351 dolphins occur in the Hawaiian stock (Carretta et al., 2009). An abundance of 20,479 Risso's dolphins has been estimated for the western North Atlantic stock and 1,589 Risso's dolphins in the northern Gulf of Mexico stock (Waring et al., 2009).

Risso's dolphin inhabits deep oceanic and continental slope waters from the tropics through the temperate regions (Leatherwood et al., 1980; Jefferson et al., 1993; Baird, 2009b). They occur predominantly at steep shelf-edge habitats, between 400 and 1,000 m (1,300 and 3,281 ft) deep with water temperatures commonly between 15 and 20°C and rarely below 10°C (Baird, 2009b). They are commonly found in the north-central Gulf of Mexico and in the northwestern Atlantic. Seasonal migrations for Japan and the North Atlantic populations have been apparent, although seasonal variation in their movement patterns elsewhere have not been studied (Kasuya, 1971; Mitchell 1975). No data on breeding grounds are available, and Risso's dolphins have been known to calve year round, but peak breeding times differ by habitat. In the North Atlantic, breeding peaks in the summer, while in Japan breeding peaks in summer-fall, and in California, breeding peaks in fall-winter (Jefferson et al., 2008).

Life history data for Risso's dolphins are poorly known, largely being derived from strandings or the result of drive fisheries. Risso's dolphins appear to sexually mature at ages 8 to 10 at an average length of 2.7 m (8.9 ft). The gestation period appears to be 13-14 months, with a 2.4 year calving interval. Lactation appears to last for 1-1.5 years (Amano and Miyazaki, 2004). However it should be noted that these values were derived from one school, and may not be representative for the entire species.

Swim speeds from Risso's dolphins were recorded at 2 to 12 km/hr (1.1 to 6.5 kts) off Santa Catalina Island (Shane, 1995). Risso's dolphins feed predominantly on neritic and oceanic squid species, probably primarily feed at night (Baird, 2009b). Dive times up to 30 min have been reported for this species (Jefferson et al. 2008).

Audiograms for Risso's dolphins indicate their hearing RLs equal to or less than approximately 125 dB in frequencies ranging from 1.6 to 110 kHz (Nachtigall et al., 1995). Phillips et al. (2003) reported that Risso's dolphins are capable of hearing frequencies up to 80 kHz. Optimal underwater hearing occurs between 4 and 80 kHz, with hearing threshold levels from 63.6 to 74.3 dB RL. Other audiograms obtained on Risso's dolphin (Au et al., 1997) confirm previous measurements and demonstrate hearing thresholds of 140 dB RL for a 1-second 75 Hz signal (Au et al., 1997; Croll et al., 1999). Au et al. (1997) estimated the effects of the ATOC source on false killer whales and on Risso's dolphins. The ATOC source transmitted 75-Hz, 195 dB SL acoustic signal to study ocean temperatures. The hearing sensitivity was measured for Risso's dolphins and their thresholds were found to be 142.2 dB RL $\pm$ 1.7 dB for the 75 Hz pure tone signal and 140.8 dB RL $\pm$ 1.1 dB for the ATOC signal (Au et al., 1997).

Risso's dolphins produce sounds as low as 0.1 kHz and as high as 65 kHz. Their dominant frequencies are between 2 to 5 kHz and at 65 kHz (Watkins, 1967; Au, 1993; Croll et al., 1999; Phillips et al., 2003). The maximum peak-to-peak SL, with dominant frequencies at 2 to 5 kHz, is about 120 dB (Au, 1993). In one experiment conducted by Phillips et al. (2003), clicks were found to have a peak frequency of 65 kHz, with 3 dB bandwidths at 72 kHz and durations ranging from 40 to 100 microsec. In a second experiment, Phillips et al. (2003) recorded clicks with peak frequencies up to 50 kHz, with 3 dB bandwidth at 35 kHz with durations ranging from 35 to 75 microsec. SLs were up to 208 dB. The behavioral and acoustical results from these experiments provided evidence that Risso's dolphins use echolocation. Estimated SLs of echolocation clicks can reach up to 216 dB (Phillips et al., 2003). Bark vocalizations consisted of highly variable burst pulses and have a frequency range of 2 to 20 kHz. Buzzes consisted of a short burst pulse of sound around 2 seconds in duration with a frequency range of 2.1 to 22 kHz. Low frequency, narrowband grunt vocalizations ranged between 400 and 800 Hz. Chirp vocalizations were slightly higher in frequency than the grunt vocalizations, ranging in frequency from 2 to 4 kHz. There are no available data regarding seasonal or geographical variation in the sound production of Risso's dolphin.

4.2.17 SHORT-BEAKED COMMON DOLPHIN (*DELPHINUS DELPHIS*) AND LONG-BEAKED COMMON DOLPHIN (*DELPHINUS CAPENSIS*)

The two common dolphin species are the short-beaked and long-beaked common dolphin. In addition, a geographic form of the long-beaked common dolphin is recognized—the Indo-Pacific common dolphin (*Delphinus capensis tropicalis*). The short-beaked common dolphin is classified as a least concern (lower risk) species, and the long-beaked common dolphin is classified as a data deficient species by the IUCN. Common dolphins are not listed as threatened or endangered under the ESA nor are categorized as depleted under the MMPA. The global population for all common dolphin species is unknown. Short-beaked common dolphins are the most abundant species at an estimate of 3,000,000 in the ETP (Jefferson et al., 2008). In the California/Oregon/Washington stock, there are an estimated 392,733 dolphins while an estimated 120,743 short-beaked common dolphins are estimated for the western North Atlantic stock (Carretta et al., 2009; Waring et al., 2009). There are also an estimated 61,000 in the eastern Atlantic, 96,000 in the Black Sea, and 75,000 in the Celtic Sea (Jefferson et al., 2008). There are little data available on abundance estimates of long-beaked common dolphins. The abundance of long-beaked common dolphins in the California/Oregon/Washington waters is 15,335 animals while 15,000 to 20,000 long-beaked common dolphins are estimated to occur in South African waters (Jefferson et al., 2008; Carretta et al., 2009).

Short-beaked and long-beaked common dolphins are distributed worldwide in temperate, tropical, and subtropical oceans, primarily along continental shelf and steep bank regions where upwelling occurs (Jefferson et al. 2008; Perrin, 2009). They seem to be most common in the coastal waters of the Pacific Ocean, usually beyond the 200-m (656-ft) isobath and north of 50°N in the Atlantic Ocean (Croll et al., 1999). Long-beaked common dolphins, however, seem to prefer shallower, warmer waters that are closer to the coast (Perrin, 2009). They are often found within 180 km (97.2 nmi) of the coast (Jefferson et al., 2008). Long-beaked common dolphins occur around West Africa, from Venezuela to Argentina in the western Atlantic Ocean, from southern California to central Mexico and Peru in the eastern Pacific Ocean, around Korea, southern Japan, and Taiwan in the western Pacific, and around Madagascar and South Africa. Indo-Pacific common dolphins are only known to occur in the northern Indian Ocean and in Southeast Asia. No breeding grounds are known for common dolphins (Croll et al., 1999). Calving peaks during May and June both in the northeastern Atlantic and North Pacific.

Common dolphins feed on a wide variety of fish and squids. The diet varies with season and with region (Evans, 1994). Gestation is estimated to take 10-12 months. The calving interval varies regionally, from 1 to 3 years. The age of sexual maturity also varies regionally from 3 to 12 years for males and 2 to 8 years for females. The maximum age reported is 30 years old (Perrin, 2009).

Swim speeds for *Delphinus* spp. have been measured at 5.8 km/hr (3.1 kts) with maximum speeds of 16.2 km/hr (8.7 kts); but in other studies, common dolphins have been recorded at swimming up to 37.1 km/hr (20 kts) (Hui, 1987; Croll et al., 1999). Dive depths range between 9 and 200 m (30 and 656 ft), with a majority of dives 9 to 50 m (30 to 164 ft) (Evans, 1994). The deepest dive recorded for these species was 260 m (850 ft) (Evans, 1971). The maximum dive duration has been documented at 5 min (Heyning and Perrin, 1994). The deepest foraging dive recorded was 200 m (656 ft) (Evans, 1994).

Common dolphins produce sounds as low as 0.2 kHz and as high as 150 kHz, with dominant frequencies at 0.5 to 18 kHz and 30 to 60 kHz (Caldwell and Caldwell, 1968; Popper, 1980; Au, 1993; Moore and Ridgway, 1995). Signal types consist of clicks, squeals, whistles, and creaks (Evans, 1994). Whistles of short-beaked common dolphins range between 7.4 and 13.6 kHz, while the whistles of long-beaked common dolphins ranges from 7.7 to 15.5 kHz (Oswald et al., 2003). Most of the energy of echolocation clicks is concentrated between 15 and 100 kHz (Croll et al., 1999). The maximum peak-to-peak SL of common dolphins is 180 dB. In the North Atlantic, the mean SL was approximately 143 dB with a maximum of 154 dB (Croll et al., 1999). There are no available data regarding seasonal or geographical variation in the sound production of common dolphins.

4.2.18 FRASER'S DOLPHIN (*LAGENODELPHIS HOSEI*)

Fraser's dolphin is classified as a data deficient species by the IUCN but is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. The global population for this species is unknown. Abundances or densities of Fraser's dolphins only exist for a limited number of regions: in the ETP, the Fraser's abundance has been estimated as 289,300 Fraser's dolphins; in the eastern Sulu Sea the abundance is estimated as 13,518 dolphins; and in Hawaiian waters, the Fraser's abundance is estimated as 16,836 dolphins (Carretta et al., 2009; Dolar, 2009). Although the Fraser's dolphin is known to occur rarely in the U.S. Gulf of Mexico, no current abundance estimate is available for this dolphin in the northern Gulf (Waring et al., 2009).

Fraser's dolphins occur primarily in tropical and subtropical waters (Croll et al., 1999; Dolar, 2009). They are found in the Atlantic, Pacific, and Indian Oceans. This species is an oceanic species that is most commonly found in deep waters (1,500 to 2,000 m [4,921 to 6,562 ft]) usually 15 to 20 km (8 to 11 nmi) from shore or where deepwater approaches the shore, such as occurs in the Philippines, Taiwan, some Caribbean islands, and the Indonesian-Malay archipelago (Jefferson et al., 2008). Breeding areas and seasonal movements of this species have not been confirmed. However, in Japan, calving appears to peak in the spring and fall. There is some evidence that calving occurs in the summer in South Africa (Dolar, 2009). Sexual maturity occurs at age 5 to 8 for females and 7 to 10 years old for males (Amano *et al.*, 1996). The calving interval for this species appears to be about 2 years (Dolar, 2009).

Swim speeds of Fraser's dolphin have been recorded between 4 and 7 km/hr (2.2 and 3.8 kts) with swim speeds up to 28 km/hr (15 kts) when escaping predators (Croll et al., 1999). Several foraging depths have been recorded. Based on prey composition, it is believed that Fraser's dolphins feed at two depth horizons in the ETP. The shallowest depth in this region is no less than 250 m (820 ft) and the deepest is no less than 500 m (1640 ft). In the Sulu Sea, they appear to feed near the surface to at least 600 m

(1,968 ft). In South Africa and in the Caribbean, they were observed feeding near the surface (Dolar et al., 2003). According to Watkins et al. (1994), Fraser's dolphins herd when they feed, swimming rapidly to an area, diving for 15 seconds or more, surfacing and splashing in a coordinated effort to surround the school of fish. Dive durations are not available.

There is no direct measurement of the hearing sensitivity of Fraser's dolphins (Ketten, 2000; Thewissen, 2002). Fraser's dolphins produce sounds ranging from 4.3 to over 40 kHz (Leatherwood et al., 1993; Watkins et al., 1994). Echolocation clicks are described as short broadband sounds without emphasis at frequencies below 40 kHz, while whistles were frequency-modulated tones concentrated between 4.3 and 24 kHz. Whistles have been suggested as communicative signals during social activity (Watkins et al., 1994). There are no available data regarding seasonal or geographical variation in the sound production of Fraser's dolphins. Source levels were not available.

4.2.19 COMMON BOTTLENOSE DOLPHIN *(TURSIOPS TRUNCATUS)*

The bottlenose dolphin is classified as least concern (lower risk) by the IUCN; this species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. The global population for the bottlenose dolphin is unknown. Estimates of 243,500 have been documented in the ETP, and an estimated 317,000 inhabit the waters of Japan (Jefferson et al., 2008). Off the Pacific coast of the U.S., 3,495 bottlenose dolphins were estimated (Carretta et al., 2009). A total of 7,000 bottlenose dolphins were estimated in the Black Sea and a minimum of 2,000 to 3,000 animals have been estimated for Shark Bay, Australia (Jefferson et al., 2008). The abundance of the western North Atlantic offshore and coastal stocks stock of bottlenose dolphins are 81,588 and 39,977, respectively, with 39,087 bottlenose dolphins found in the northern Gulf of Mexico (Waring et al., 2009).

The bottlenose dolphin is distributed worldwide in temperate to tropical waters. In North America, they inhabit waters with temperatures ranging from 10 to 32°C (50 to 89°F) (Wells and Scott, 2009). They are primarily found in coastal waters, but they also occur in diverse habitats ranging from rivers and protected bays to oceanic islands and the open ocean, over the continental shelf, and along the shelf break (Scott and Chivers, 1990; Sudara and Mahakunlayanakul, 1998; Wells and Scott, 2009). Bottlenose dolphins are found in the Pacific, Atlantic, and Indian oceans. The species' northern range extends to the United Kingdom and northern Europe (Croll et al., 1999). The species' southern range extends as far south as Tierra del Fuego, South Africa, Australia, and New Zealand (Wells and Scott, 2009). Seasonal movements vary between inshore and offshore locations and year-round home ranges (Croll et al., 1999; Wells and Scott, 2009). Calving season is generally year-round with peaks occurring from early spring to early fall (Scott and Chivers, 1990). There are no known breeding grounds.

Common bottlenose females can live up to 57 years old while the maximum age for males is 48 (Wells and Scott, 1990). Females reach sexual maturity at ages 5 to 13, while males mature at ages 9 to 14 (Wells and Scott, 2009). Females can remain reproductive for long period of time, with the oldest mother reported to be age 48 (Wells and Scott, 1990). Gestation last approximately 12 months.

Sustained swim speeds for bottlenose dolphins range between 4 and 20 km/hr (2.2 and 10.8 kts) and may reach speeds as high as 29.9 km/hr (16.1 kts) (Croll et al., 1999). Dive times range from 38 seconds to 1.2 min but have been known to last as long as 10 min (Mate et al., 1995; Croll et al., 1999). The dive depth of a bottlenose dolphin in Tampa Bay, Florida, was measured at 98 m (322 ft) (Mate et al., 1995). The deepest dive recorded for a bottlenose dolphin is 535 m (1,755 ft) reached by a trained individual (Ridgway, 1986).

Bottlenose dolphins hear underwater sounds in the range of 150 Hz to 135 kHz (Johnson, 1967; Ljungblad et al., 1982). Their best underwater hearing occurs at 15 kHz, where the threshold level range is 42 to 52 dB RL (Sauerland and Dehnhardt, 1998). Bottlenose dolphins also have good sound location abilities and are most sensitive when sounds arrive directly towards the head (Richardson et al., 1995).

Bottlenose dolphins produce sounds as low as 0.05 kHz and as high as 150 kHz with dominant frequencies at 0.3 to 14.5 kHz, 25 to 30 kHz, and 95 to 130 kHz (Johnson, 1967; Popper, 1980; McCowan and Reiss, 1995; Schultz et al., 1995; Croll et al., 1999; Oswald et al., 2003). The maximum SL produced is 228 dB (Croll et al., 1999). Bottlenose dolphins produce a variety of whistles, echolocation clicks and burst-pulse sounds. Echolocation clicks, with peak frequencies from 40 to 130 kHz, are hypothesized to be used in navigation, foraging, and predator detection (Au, 1993; Houser et al., 1999; Jones and Sayigh, 2002). According to Au (1993), sonar clicks are broadband, ranging in frequency from a few kilohertz to more than 150 kHz, with a 3 dB bandwidth of 30 to 60 kHz (Croll et al., 1999). The echolocation signals usually have a 50 to 100 microseconds duration with peak frequencies ranging from 30 to 100 kHz and fractional bandwidths between 10 and 90 % of the peak frequency (Houser et al., 1999). Burst-pulses, or squawks, are commonly produced during social interactions. These sounds are broadband vocalizations that consist of rapid sequences of clicks with inter-click intervals less than 5 milliseconds. Burst-pulse sounds are typically used during escalations of aggression (Croll et al., 1999).

Each individual bottlenose dolphin has a fixed, unique FM pattern, or contour whistle called a signature whistle. These signal types have been well studied and are presumably used for recognition, but may have other social contexts (Jones and Sayigh, 2002; Frankel, 2009). Signature whistles have a narrow-band sound with the frequency commonly between 4 and 20 kHz, duration between 0.1 and 3.6 seconds, and an SL of 125 to 140 dB (Croll et al., 1999). Jones and Sayigh (2002) reported geographic variations in behavior and in the rates of vocal production. Whistles and echolocation varied between Southport, North Carolina, the Wilmington-North Carolina Intracoastal Waterway (ICW), the Wilmington, North Carolina, coastline, and Sarasota, Florida. Dolphins at the Southport site whistled more than the dolphins at the Wilmington site, which whistled more than the dolphins at the ICW site, which whistled more than the dolphins at the Sarasota site. Echolocation production was higher at the ICW site than all of the other sites. Dolphins in all three of the North Carolina sites spent more time in large groups than the dolphins at the Sarasota site. Echolocation occurred most often when dolphins were socializing (Jones and Sayigh, 2002).

4.2.20 INDO-PACIFIC BOTTLENOSE DOLPHIN (*TURSIOPS ADUNCUS*)

Only in the last ten years has this species' taxonomy been clearly differentiated from that of the common bottlenose dolphin. Indo-Pacific bottlenose dolphins are considered data deficient by the IUCN but are not listed as threatened or endangered under the ESA nor are categorized as depleted under the MMPA. No global abundance estimates exist for the species and even regional abundance estimates are few, even though it is the most commonly observed marine mammal species in some coastal regions of the world. Estimates of Indo-Pacific bottlenose dolphins include 218 animals in Japanese waters; 1,634 to 1,934 in Australian waters; and 136 to 179 dolphins off Zanzibar, Tanzania (Wang and Yang, 2009).

Indo-Pacific bottlenose dolphins occur in warm temperate to tropical waters of the Indian Ocean and southwestern Pacific Ocean, from South Africa and the Red Sea and Persian Gulf to southern Japan, Indonesia, Malaysia, and central Australia (Jefferson et al., 2008). Considered principally a coastal species, the Indo-Pacific bottlenose dolphin occurs predominantly in continental shelf and insular shelf waters, usually in shallow coastal and inshore waters (Jefferson et al., 2008). However, movements across deep, oceanic waters have been reported (Wang and Yang, 2009).

Females reach sexual maturity at about 12-15 years of age while males mature at ages 10-15. Gestation typically lasts 12 months. The peak of the calving season is very broad, with most births occurring when the water is at its warmest. The interval between births is typically 3-6 years, but can be as low as two. The maximum age for this species may be around 50 years (Wang and Yang, 2009).

Swimming speeds range from 0.4 to 1 m/sec (0.8 to 2.2 kts) but bursts of higher speeds can reach 4.4 to 5.3 m/sec (8.6 to 10.3 kts) (Wang and Yang, 2009). Little information is known about the diving ability of the Indo-Pacific bottlenose dolphin, but dive depths and durations are thought be less than 200 m and from 5 to 10 min (Wang and Yang, 2009).

Although much is known about hearing in the common bottlenose dolphin, specific hearing data are not yet available for the Indo-Pacific bottlenose dolphin. These dolphins produce whistle and pulsed call vocalizations. Whistles range in frequency from 7 to 10 kHz (Morisaka et al., 2005). Morisaka et al. (2005) found variations in whistles between populations of Indo-Pacific bottlenose dolphins and determined that ambient noise levels were likely responsible for the whistle variability (Morisaka et al., 2005a).

4.2.21 PANTROPICAL SPOTTED DOLPHIN *(STENELLA ATTENUATA)*

The pantropical spotted dolphin is one of the most abundant dolphin species in the world. This species is listed as a least concern (lower risk) species by the IUCN. The pantropical dolphin is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. In the ETP, 640,000 northeastern offshore spotted dolphins have been estimated, while an estimated 4,439 occur in the western North Atlantic, and 29,311 dolphins are estimated in the northern Gulf of Mexico (Perrin, 2009a; Waring et al., 2009). In the Hawaiian EEZ, there are an estimated 10,260 pantropical spotted dolphins (Carretta et al., 2009). In the early 1990s, about 438,000 were estimated to occur in Japanese waters (Jefferson et al., 2008).

Pantropical spotted dolphins occur throughout tropical and sub-tropical waters from roughly 40°N to 40°S in the Atlantic, Pacific, and Indian Oceans (Perrin, 2009a). These dolphins typically are oceanic but are found close to shore in areas where deep water approaches the coast, as occurs in Taiwan, Hawaii, and the western coast of Central America (Jefferson et al., 2008). Pantropical spotted dolphins also occur in the Persian Gulf and Red Sea.

Little is known of the life history of pantropical spotted dolphins. Females achieve sexual maturity at ages of 9 to 11 years and males mature at 12 to 15 years old. Gestation lasts approximately 11.5 months. Calving intervals average two to three years, but do vary with population status. The breeding season is diffused seasonally, with region specific peaks occurring in the different populations (Perrin, 2009a).

Pantropical spotted dolphins have been recorded swimming at speeds of 4 to 19 km/hr (2.2 to 10.3 kts), with bursts up to 22 km/hr 12 kts (Perrin, 2009a). Pantropical spotted dolphins dive to at least 170 m (557.7 ft), with most of their dives to between 50 and 100 m (164 and 328 ft) for 2 to 4 min, and most foraging occurs at night (Stewart, 2009). Pantropical spotted dolphins off Hawaii have been recorded to dive at a maximum depth of 122 m (400 ft) during the day and 213 m (700 ft) during the night (Baird et al., 2001). The average dive duration for the pantropical spotted dolphins is 1.95 min for depths as deep as 100 m (Scott et al., 1993). Dives of up to 3.4 min have been recorded (Perrin, 2009a).

Pantropical spotted dolphins produce whistles with a frequency range of 3.1 to 21.4 kHz (Richardson et al., 1995). They also produce click sounds that are typically bimodal in frequency with peaks at 40 to 60 kHz and 120 to 140 kHz with SLs up to 220 dB re 1 µPa (Schotten et al., 2004). There are no direct hearing measurements for the pantropical spotted dolphin.

4.2.22 STRIPED DOLPHIN (*STENELLA COERULEOALBA*)

Striped dolphins are a lower risk (least concern) species classified by the IUCN, is not listed as threatened or endangered under the ESA, nor is it categorized as depleted under the MMPA. Striped dolphins are known to be the most abundant species in the Mediterranean Sea, with an estimated 225,000 individuals (Jefferson et al., 2008; Archer, 2009). In the ETP, there is an estimated 1 million striped dolphins (Jefferson et al., 2008). In the western North Atlantic, there is an estimated 94,462, and in the northern Gulf of Mexico there is an estimated 3,325 (Waring et al., 2009). Off the Pacific coast of the U.S., there are an estimated 17,925, and in the Hawaiian EEZ there is an estimated 10, 385 striped dolphins (Carretta et al., 2009).

Striped dolphins are common in tropical and warm-temperate waters. Their full range is unknown, but they are known to range from the Atlantic coast of northern South America up to the eastern seaboard of North America, with a northern limit following the Gulf Stream. They are found in the eastern North

Atlantic, south of the United Kingdom, and are the most frequently observed dolphin in the Mediterranean Sea. Striped dolphins have also been documented off the coast of several countries bordering the Indian Ocean. Striped dolphins are found outside the continental shelf, over the continental shelf, and are associated with convergence zones and waters influenced by upwelling. Temperature ranges for these dolphins are reported at 10 to 26°C (50 to 79°F) but most often between 18° and 22°C (64 and 72°F).

In the Ligurian Sea, striped dolphins are commonly found along the Ligurian Sea Front, which has water depths of 2,000 to 2,500 m (6,562 to 8,202 ft). It is believed that they have a high abundance in this area due to a high biological productivity, which attracts and sustains their prey. Striped dolphins may be more active at night because the fish and cephalopods that they eat migrate to the surface at night (Gordon et al., 2000).

Females achieve sexual maturity at ages of 5 to 13 years, while males mature at ages of 7 and 15 years. Mating is seasonal and gestation lasts 12 to 13 months. The maximum age reported for both sexes is 57.5 years (Archer, 2009).

Average swim speeds of 11 km/hr (5.9 kts) were measured from striped dolphins in the Mediterranean (Archer and Perrin, 1999). Based on stomach contents, it is predicted that striped dolphins may be diving down 200 to 700 m (656 to 2,297 ft) to feed (Archer, 2009). Dive times are unknown for this species.

The behavioral audiogram developed by Kastelein and Hagedoorn (2003) shows hearing capabilities from 0.5 to 160 kHz. The best underwater hearing of the species appears to be at from 29 to 123 kHz (Kastelein et al., 2003). Striped dolphins produce whistle vocalizations ranging from 6 to >24 kHz with peak frequencies ranging from 8 to 12.5 kHz (Thomson and Richardson, 1995).

4.2.23 ATLANTIC SPOTTED DOLPHIN *(STENELLA FRONTALIS)*

The Atlantic spotted dolphin is classified as a data deficient species by the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. The global abundance of the Atlantic spotted dolphin is unknown. In the western North Atlantic, the population estimated for most of the U.S. Atlantic waters (between Florida and Maryland) is 47,400, and the most current stock estimate for the northern Gulf of Mexico is an estimated 37,611 Atlantic spotted dolphins (Waring et al., 2009).

The Atlantic spotted dolphin is found only in the tropical and warm-temperate waters of the Atlantic Ocean. They are commonly found around the southeastern U.S. and the Gulf coasts, in the Caribbean, and off West Africa. They inhabit waters around the continental shelf and the continental shelf-break. Atlantic spotted dolphins are usually near the 200 m (656 ft) contour, but they occasionally swim closer to shore in order to feed. A wide variety of prey species have been reported, including epipelagic and mesopelagic fishes, benthic invertebrates and squids. There may be difference in foraging preferences between coastal and pelagic forms (Perrin, 2009b).

Females attain sexual maturity at ages 8 to 15. The mean interval between calves is three years with a range of one to five years, and nursing can last up to five years long (Perrin, 2009b).

In the Gulf of Mexico, Atlantic spotted dolphins were recorded diving 40 to 60 m (131 to 197 ft) deep (Perrin, 2009b). The average dive time was around 6 min, and most, if not all dives were less than 10 min in duration (Perrin, 2009b).

There are no current hearing data on Atlantic spotted dolphins. Atlantic spotted dolphins produce a variety of sounds, including whistles, whistle-squawks, buzzes, burst-pulses, synch pulses, barks, screams, squawks, tail slaps, and echolocation clicks. Like other odontocetes, they produce broadband, short duration echolocation signals. Most of these signals have a bimodal frequency distribution. They project relatively high-amplitude signals with a maximum SL of about 223 dB (Au and Herzing, 2003). Their broadband clicks have peak frequencies between 60 and 120 kHz. Dolphins produce whistles with frequencies generally in the human audible range, below 20 kHz. These whistles often have harmonics which occur at integer multiples of the fundamental and extend beyond the range of human hearing. Atlantic spotted dolphins have also been recorded making burst pulse squeals and squawks, along with bi-modal echolocation clicks with a low-frequency peak between 40 and 50 kHz and a high-frequency peak between 110 and 130 kHz. Many of the vocalizations from Atlantic spotted dolphins have been associated with foraging behavior (Herzing, 1996). There are no available data regarding seasonal variation in the sound production of *Stenella* dolphins, although geographic variation is evident. Peak-to-peak SLs as high as 210 dB have been measured (Au et al., 1998; Au and Herzing, 2003).

4.2.24 SPINNER DOLPHIN (*STENELLA LONGIROSTRIS*)

The spinner dolphin is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. This species is classified as a data deficient species by the IUCN. Spinner dolphins are one of the most abundant dolphin species in the world. In the ETP there is an estimated 1,250,000 (Jefferson et al., 2008). In the northern Gulf of Mexico, there are an estimated 1,989 individuals in the stock while in the Pacific there are an estimated 2,805 spinner dolphins in the Hawaiian stock (Carretta et al., 2009; Waring et al., 2009).

Spinner dolphins are pantropical, occurring in tropical and most subtropical oceanic waters from about 40°S to 40°N, except in the Mediterranean Sea (Jefferson et al. 2008). Spinner dolphins are found in coastal regions of Hawaii, the eastern Pacific, Indian Ocean, and off Southeast Asia, usually resting in the shallow waters of bays of oceanic islands and atolls. This pelagic form preys on mesopelagic fish and squids (Perrin, 2009c). The dwarf species occurs only in the shallow waters of Southeast Asia and northern Australia is found in shallower waters in the Gulf of Thailand, Timor Sea, and Arafura Sea (Jefferson et al., 2008; Perrin, 2009c). The dwarf form preys on invertebrates and reef fishes (Perrin 2009c).

Females achieve sexual maturity at an age of four to seven years, while males mature at ages of seven to ten years. Breeding is seasonal and the timing varies between populations. Gestation takes approximately 10 months and the average inter-calf interval is 3 years. Females nurse for one to two years (Perrin 2009c).

Hawaiian spinner dolphins have swim speeds ranging from 2.6 to 6 km/hr (1.4 to 3.2 kts) (Norris et al., 1994). Based on where their prey is located in the water column, spinner dolphins likely dive as deep as 600 m (1,969 ft) (Perrin, 2009c). Dive durations are unknown for this species. Spinner dolphins are known for their aerial behavior, spinning up to seven times during one aerial leap from the water, reaching heights of 3 m (9 ft) above the water surface with an airborne time of 1.25 sec (Fish et al., 2006).

There are no current hearing data on spinner dolphins. The amount and variety of signal types generally increases with increasing social activity, particularly in Hawaiian spinner dolphins (Frankel, 2009). Spinner dolphins produce burst pulse calls, echolocation clicks, whistles, and screams (Norris et al., 1994; Bazua-Duran and Au, 2002). The results of a study on spotted and spinner dolphins conducted by Lammers et al. (2003) revealed that the whistles and burst pulses of the two species span a broader frequency range than is traditionally reported for delphinids. The fundamental frequency contours of whistles occur in the human hearing range, but the harmonics typically reach 50 kHz and beyond. Additionally, the burst pulse signals are predominantly ultrasonic, often with little or no energy below 20 kHz (Lammers et al., 2003).

4.2.25 CLYMENE DOLPHIN (*STENELLA CLYMENE*)

Clymene dolphins are one of the more poorly known dolphin species and are classified as data deficient by the IUCN. This dolphin species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. Global population estimates are unknown, but there are an estimated 6,086 in the western North Atlantic and an estimated 6,575 in the northern Gulf of Mexico (Waring et al., 2009).

Clymene dolphins are only found in the tropical to warm-temperate waters of the Atlantic Ocean from New Jersey in the northwestern Atlantic Ocean to Brazil and West Africa (Angola) in the South Atlantic Ocean (Jefferson et al., 2008). Most sightings of Clymene dolphins have been in deep, oceanic waters, but they have also been observed close to shore in areas where deep water approaches the coast. Very little is known about their ecology, although they are known to feed on mesopelagic fish and squids (Jefferson, 2009). There are no published accounts of the life history of Clymene dolphins.

There are no measurements for Clymene dolphin hearing abilities. Clymene dolphins generally produce a higher frequency whistle than other *Stenella* species. The Clymene dolphin whistle frequency was measured ranging from 6.3 to 19.2 kHz (Mullin et al., 1994).

4.2.26 PEALE'S DOLPHIN (*LAGENORHYNCHUS AUSTRALIS*)

Peale's dolphins are classified at data deficient under the IUCN, are not listed as threatened or endangered under the ESA, nor are categorized as depleted under the MMPA. Although the only abundance estimate for this species is 200 individuals in southern Chilean waters, the species is considered to be fairly abundant throughout its range (Jefferson et al., 2008). Peale's dolphins inhabit the open coastal waters of Patagonia, Tierra del Fuego, and Chile as well as the deep, protected bays and channels of southern Chile (Goodall, 2009). Peale's dolphins are routinely observed in the waters of the Falkland Islands (Jefferson et al. 2008). The dive sequences Peale's dolphins are usually three short dives followed by one longer dive with dive durations from 3 to 157 seconds, averaging 28 seconds. Peale's dolphins forage on octopus, squid, demersal and bottom fish (Goodall, 2009). There is very little known about the life history of Peale's dolphin.

Species in this genus produce sounds as low as 0.06 kHz and as high as 325 kHz with dominant frequencies at 0.3 to 5 kHz, 4 to 15 kHz, 6.9 to 19.2 kHz, and 60 to 80 kHz (Popper, 1980b; Richardson et al., 1995). Peale's dolphin vocalizations were recorded in the Chilean channel with broadband clicks at 5 to 12 kHz and narrowband clicks at 1 to 2 kHz bandwidths (Goodall, 2009). Peale's dolphin SLs were recorded at low levels of 80 dB re 1 µPa @ 1 m with a frequency of 1 to 5 kHz and were mostly inaudible at more than 20 m (65.6 ft) away (Croll et al., 1999).

4.2.27 DUSKY DOLPHIN (*LAGENORHYNCHUS OBSCURUS*)

The dusky dolphin is listed as data deficient species under the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. No global population estimates are available for this species. Dusky dolphins occur off New Zealand, central and southern South America, southwestern and southern Africa, southern Australia, and several islands in the South Atlantic and southern Indian Oceans (Jefferson et al., 2008; Van Waerebeek and Würsig, 2009). Dusky dolphins occur primarily in neritic waters but have been observed in deep waters when it approaches close to continental or island coasts (Van Waerebeek and Würsig, 2009). Although no well-defined seasonal migration patterns are apparent, this species are known to move over a range of 780 km (421 nmi) (Van Waerebeek and Würsig, 2009). Dusky dolphins off Argentina and New Zealand move inshore-offshore on both a diurnal and a seasonal scale. Dusky dolphins feed on a wide variety of fish and squid species.

Most births in Peru and New Zealand occur in late winter while Argentinian duskies give birth in summer. Sexual maturity for females occurs at 4.3 to 5 years of age in Peru, while requiring 6.3 years in Argentina. Peruvian males mature at 3.8 to 4.7 years. Gestation lasts 13 months; nursing lasts 12 months and is typically followed by a 3.7 month resting period (Van Waerebeek and Würsig, 2009).

Off Argentina, the mean dive time for dusky dolphins was 21 sec, with shorter dives during the day and longer dives at night (Würsig, 1982). Dusky dolphins in New Zealand swim at mean routine speeds between 4.5 and 12.2 km/hr (2.4 and 6.6 kts) (Würsig and Würsig, 1980).

There are no hearing data available for this species. Dusky dolphins produce bimodal echolocation clicks, with lower frequency clicks from 40 to 50 kHz and high frequency clicks between 80 and 110 kHz (Van Waerebeek and Würsig, 2009). Au and Würsig (2004) reported echolocation clicks between 30 and 130 kHz, with a maximum SL of 210 dB re 1 µPa @ 1 m.

4.2.28 ATLANTIC WHITE-SIDED DOLPHIN *(LAGENORHYNCHUS ACUTUS)*

The Atlantic white-sided dolphin is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA; this species is listed as a least concern (lower risk) species under the IUCN. The estimated population in the North Atlantic is 150,000 to 300,000 Atlantic white-sided dolphins (Cipriano, 2009). In the western North Atlantic, there are an estimated 63,368 Atlantic white-sided dolphins (Waring et al., 2009), and in the eastern North Atlantic off the western coast of Scotland, there are an estimated 96,000 Atlantic white-sided dolphins (Jefferson et al., 2008).

Atlantic white-sided dolphins are found only in the cold-temperate waters of the North Atlantic from about 38°N (south of U.S. Cape Cod) and the Brittany coast of France north to southern Greenland, Iceland, and southern Svalbard (Jefferson et al., 2008). They are generally found in continental shelf and slope waters but are also observed in shallow and oceanic waters. Cape Cod is the southern limit to the Atlantic white-sided dolphin, with an eastern limit of Georges Bank and Brittany. It has been noted that there are seasonal shifts in abundance for the Atlantic white-sided dolphin (Jefferson et al., 2008). Major prey species include herring, small mackerel, gadid fishes, smelt, hake, sand lance and squid (Reeves et al., 1999). Calving occurs during the summer months with peaks in June and July (Croll et al., 1999; Jefferson et al., 2008).

Females reach sexual maturity at ages six to twelve, while males mature at ages seven to eleven. Gestation lasts about 11 months and nursing lasts approximately 18 months (Cipriano, 2009). Calving peaks in the summer in the western Atlantic, but it is extended for several months in the eastern Atlantic (Weinrich et al., 2001). Some animals have been observed both pregnant and lactating, which suggests that reproduction may occur annually. The oldest individuals observed were 22 and 27 years old for males and females (Cipriano, 2009).

Atlantic white-sided dolphins are probably not deep divers. A tagged dolphin dove for an average of 38.8 seconds with 76 % of dives lasting less than 1 minute (Mate et al., 1994). This dolphin also swam at an average speed of 5.7 km/hr (3.1 kts) (Mate et al., 1994). The maximum dive time recorded from a tagged animal was 4 min (Cipriano, 2009).

There are no available hearing data on the Atlantic white-sided dolphin. Whistle vocalizations of Atlantic white-sided dolphins have been recorded with a dominant frequency of 6 to 15 kHz (Richardson et al., 1995). The average estimated SL for an Atlantic white-sided dolphin is approximately 154 dB re 1 µPa @ 1 m with a maximum at 164 dB re 1 µPa @ 1 m (Croll et al., 1999).

4.2.29 WHITE BEAKED DOLPHIN (*LAGENORHYNCHUS ALBIROSTRIS*)

The white beaked dolphin is classified as a least concern (lower risk) species under the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. There is no global population estimate for this species. A total of 7,856 white-beaked dolphins are estimated in the North Sea and adjacent waters (Hammond et al., 2002) while 2,003 white-beaked dolphins are estimated in the western North Atlantic (Waring et al., 2009).

White-beaked dolphins are distributed in the temperate and subarctic North Atlantic Ocean and share a similar habitat to that of the Atlantic white-sided dolphin but with a more northern range (Evans, 1987; Reeves and Leatherwood, 1994; Kinze, 2009). Reports of white-beaked dolphins in the Mediterranean Sea are questionable (Jefferson et al., 2008; Kinze, 2009). This species is distributed principally in continental shelf waters of these four high density areas: Labrador Shelf including southwestern Greenland, Iceland, Scotland/North Sea/Irish Sea, Norway coast to White Sea. Prey species are predominantly fish, although the Scottish population also preys on celphalopods. Prey species vary regionally, reflecting the prevalence of local fish species (Kinze, 2009).

Females achieve sexual maturity at a mean age of 8.7 years and males at a mean age of 11.6. Male testis size increase significantly during the mating season that ranges from July to August. Gestation lasts approximately eleven months. Intercalf intervals are not known, but may be quite long, since pregnant females are rarely found among stranded animals. The maximum age reported for females is 34 years old (Kinze, 2009)

Nachtigall et al., (2008) performed AEP measurements on the white beaked dolphin. An adult male was measured to have a hearing threshold near 100 dB at 152 kHz, and 121 dB at 181 kHz (Nachtigall et al., 2008). Clicks produced by white-beaked dolphins resemble those by bottlenose dolphins. They make short, broadband clicks with peak frequencies of about 120 kHz (Rasmussen et al., 2002). They are approximately 10 to 30 ms in duration. Some clicks have a secondary peak of 250 kHz. The maximum sound level was recorded at 219 dB re 1 µPa @ 1 m and was measured at a range of 22 m (72.2 ft) (Rasmussen et al., 2002). The minimum recorded sound level was 189 dB at a distance of 1.5 m (4.9 ft) from the dolphin (Rasmussen et al., 2002).

4.2.30 HOURGLASS DOLPHIN (*LAGENORHYNCHUS CRUCIGER*)

Hourglass dolphins are not listed as threatened or endangered under the ESA, are not categorized as depleted under the MMPA, but are listed as least concern/low risk species under the IUCN. There is no global population abundance available, but Kasamatsu and Joyce (1995) estimated the abundance of hourglass dolphins south of the Antarctic Convergence as 144,300 dolphins.

Hourglass dolphins are oceanic and occur in the Southern Hemisphere from 45°S to the pack ice or about 60°S in Antarctic and subantarctic waters that range in temperature from 0.3° to 13.4°C (32.54° to 56.1°F) (Goodall, 2009a). Although an oceanic species, hourglass dolphins have been sighted near islands and over banks and areas where the water is turbulent (Goodall, 2009a). Nothing is known about the migratory movements of this species but they move seasonally into nearshore or subantarctic waters. Hourglass dolphins feed on small fish, squid, crustaceans and polycheates. Very little is known of the life history of these dolphins (Goodall, 2009a).

There are no available hearing data for this species. Tougaard and Kyhn (2010) recently recorded echolocation clicks of hourglass dolphins with frequencies ranging from about 100 to 190 kHz, a mean peak frequency of 125 kHz, and signal duration of 150 msec.

4.2.31 PACIFIC WHITE-SIDED DOLPHIN (*LAGENORHYNCHUS OBLIQUIDENS*)

Pacific white-sided dolphins are listed as least concern/low risk species under the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. In the North Pacific Ocean, an abundance of 931,000 to 990,000 Pacific white-sided dolphins has been estimated (Jefferson et al., 2008; Black, 2009). There are an estimated 20,719 Pacific white-sided dolphins in the waters of the U.S. west coast (CA, OR, and WA) and an estimated 26,880 in the Gulf of Alaska (Angliss and Allen, 2009; Carretta et al., 2009). Some animals found in the Gulf of Alaska could also be part of the U.S. west coast stock. In Japanese waters, 30,000 to 50,000 Pacific white-sided dolphins have been estimated to occur (Nishiwaki, 1972).

Pacific white-sided dolphins are mostly pelagic and have a primarily cold temperate distribution across the North Pacific; in the western North Pacific, this species occurs from Taiwan north to the Commander and Kuril Islands while in the eastern North Pacific, it occurs from southern Gulf of California to the Aleutian Islands (Jefferson et al., 2008; Black, 2009). Pacific white-sided dolphins are distributed in continental shelf and slope waters generally within 185 km of shore and often move into coastal and even inshore waters. No breeding grounds are known for this species. From studies of the ecology of their prey, Pacific white-sided dolphins are presumed to dive from 120 to 200 m (393.7 to 656 ft), with most of their foraging dives lasting a mean of 27 sec (Black, 1994). Captive Pacific white-sided dolphins have been recorded swimming as fast as 27.7 km/hr (15.0 kts) for 2 sec intervals (Fish and Hui, 1991) with a mean travel speed of 7.6 km/hr (Black, 1994). Pacific white-sided dolphins feed on fish and squid, although the dominant prey type varies regionally (Black, 2009).

Females become sexually mature at ages eight to eleven, while males mature at ages nine to twelve. Males show a large increase in testis size during summer, indicating that this when mating occurs. Gestation lasts 11-12 months, and calves are born from May to September. Females have a four to five year calving interval. The maximum age reported is 42 for males and 46 for females (Black, 2009).

Pacific white-sided dolphins hear in the frequency range of 2 to 125 kHz when the sounds are equal to or softer than 90 dB RL (Tremel et al., 1998). This species is not sensitive to low frequency sounds (i.e., 100 Hz to 1 kHz) (Tremel et al., 1998). Pacific white-sided dolphins produce broad-band clicks that are in the frequency range of 60 to 80 kHz and that have a SL at 180 dB re 1 µPa @ 1 m (Richardson et al., 1995). There are no available data regarding seasonal or geographical variation in the sound production of *Lagenorhynchus* dolphins.

4.2.32 ROUGH-TOOTHED DOLPHIN (*STENO BREDANENSIS*)

The rough-toothed dolphin is not listed as threatened or endangered under the ESA, nor is it categorized as depleted under the MMPA; it is classified as data deficient species by the IUCN. Globally, few population estimates are available for the rough-toothed dolphin except in the ETP, where the stock was estimated at 145,900 individuals (Wade and Gerrodette, 1993), and in the U.S. Gulf of Mexico, where the stock estimate is 2,653 dolphins (Waring et al., 2009), and in Hawaiian waters, where the stock was estimated at 19,904 individuals (Carretta et al., 2009). Occurrence data are insufficient elsewhere to estimate abundances.

Rough-toothed dolphins occur in oceanic tropical and warm-temperate waters around the world and appear to be relatively abundant in certain areas; these dolphins are also found in continental shelf waters in some locations, such as Brazil (Jefferson, 2009a). In the Atlantic Ocean, they are found from the southeastern U.S. to southern Brazil and from the Iberian Peninsula and West Africa to the English Channel and North Sea. Their range also includes the Gulf of Mexico, Caribbean Sea, and the Mediterranean Sea (Jefferson, 2009a). In the Pacific, they inhabit waters from central Japan to northern Australia and from Baja California, Mexico, south to Peru. In the eastern Pacific, they are associated with warm, tropical waters that lack major upwelling (Jefferson, 2009a). Their range includes the southern Gulf of California and the South China Sea. Rough toothed dolphins are also found in the Indian Ocean, from the southern tip of Africa to Australia (Jefferson et al., 2008). Seasonal movements and breeding areas for this species have not been confirmed. They feed on fish and squid species, although the details are poorly known (Jefferson, 2009a).

Females reach sexual maturity at age 10 and males at age 14. The maximum reported age is 32-36 years, although there are indications that some individuals may live much longer (Jefferson, 2009a).

Rough-toothed dolphins are not known to be fast swimmers. They are known to skim the surface at a moderate speed (Jefferson, 2009a). Swim speeds of this species vary from 5.6 to 16 km/hr (3.0 to 8.6 kts) (Watkins et al., 1987a; Ritter, 2002). Rough-toothed dolphins can dive 30 to 70 m (98 to 230 ft) with dive duration ranging from 0.5 to 3.5 min (Watkins et al., 1987a; Ritter, 2002). Dives up to 15 min have been recorded for groups of dolphins (Miyazaki and Perrin, 1994).

Very little information is available on the hearing sensitivity of rough-toothed dolphins. Cook et al. (2005) performed AEPs on five live-stranded rough-toothed dolphins and found that these dolphins could detect sounds between 5 and 80 kHz; the authors believe that rough-toothed dolphins are likely capable of detecting frequencies much higher than 80 kHz. Rough-toothed dolphins produce sounds ranging from 0.1 kHz up to 200 kHz (Popper, 1980; Miyazaki and Perrin, 1994; Richardson et al., 1995). Clicks have peak energy at 25 kHz, while whistles have a maximum energy between 2 to 14 kHz (Norris and Evans, 1967; Norris, 1969; Popper, 1980b). There are no available data regarding seasonal or geographical variation in the sound production of this species.

4.2.33 NORTHERN RIGHT WHALE DOLPHIN *(LISSODELPHIS BOREALIS)*

The northern right whale dolphin is classified as a least concern (lower risk) species by the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. The global population in the North Pacific Ocean of the northern right whale dolphin is estimated as 68,000 animals (Jefferson et al., 2008). In the U.S. waters of California, Oregon, and Washington, 12,876 northern right whale dolphins have been estimated (Carretta et al., 2009).

This oceanic species is only found in temperate to subarctic regions of the North Pacific from roughly 34° to 54°N and 118° to 145°W (Jefferson et al., 2008; Lipsky, 2009). This range extends from the Kuril Islands (Russia) south to Japan and from the Gulf of Alaska to southern California. This species has been most often observed in waters ranging in temperature from 8 and 19°C (46.4 to 66.2°F) (Leatherwood and Walker, 1979). Northern right whale dolphins can occur near to shore when submarine canyons or other such topographic features cause deep water to be located close to the coast. Seasonally the northern right whale dolphin exhibits inshore-offshore movements in some areas, such as off southern California. Inshore movements are associated with peak abundance of squid, their primary prey (Lipsky, 2009).

There is little information on life history. Sexual maturity occurs at an age of approximately ten years old (Lipsky, 2009).

Swim speeds for northern right whale dolphins can reach 34 to 40 km/hr (18.3 to 21.6 kts) (Leatherwood and Walker, 1979; Leatherwood and Reeves, 1983). The maximum recorded dive duration is 6.25 min with a maximum dive depth of 200 m (Fitch and Brownell, 1968; Leatherwood and Walker, 1979).

There is no direct measurement of the hearing sensitivity of the northern right whale dolphin (Ketten, 2000; Thewissen, 2002). They produce sounds as low as 1 kHz and as high as 40 kHz or more, with dominant frequencies at 1.8 and 3 kHz (Fish and Turl, 1976; Leatherwood and Walker, 1979). The maximum known peak-to-peak SL of northern right whale dolphins is 170 dB (Fish and Turl, 1976).

4.2.34 SOUTHERN RIGHT WHALE DOLPHIN *(LISSODELPHIS PERONII)*

The southern right whale dolphin is not listed as threatened or endangered under the ESA, is not categorized as depleted under the MMPA, but is classified as a data deficient species by the IUCN. The global population estimate for this species is unknown and virtually nothing known regarding the population status of this species.

Southern right whale dolphins only occur in the cold temperate to subantarctic oceans of the Southern Hemisphere between 25° and 65°S; the Antarctic Convergence Zone forms the effective southern limit of this species range (Lipsky, 2009). An oceanic species, the southern right whale dolphin can be found deepwater coastal areas as well (Jefferson et al., 2008). There is little information on life history. Sexual maturity occurs at an age of approximately ten years old (Lipsky, 2009). Southern right whale dolphins can swim up to 22 km/hr (12 kts) and dive as long as 6.5 min (Cruickshank and Brown, 1981). These dolphins appear to make dives to about 200 m (656 ft) while foraging (Fitch and Brownell, 1968). The hearing sensitivity of southern right whale dolphins has not been directly measure nor is any sound production information or data available (Ketten, 2000; Thewissen, 2002).

4.2.35 SUBFAMILY CEPHALORHYNCHINAE

This group includes the Commerson's dolphin (*Cephalorhynchus commersonii*), Chilean dolphin (*Cephalorhynchus eutropia*), Heaviside's dolphin (*Cephalorhynchus heavisidii*), and Hector's dolphin (*Cephalorhynchus hectori*).

Commerson's, Chilean, and Heaviside's dolphins are classified as data deficient species while the Hector's dolphin is classified as endangered under the IUCN. None these species listed as threatened or endangered under the ESA nor are they categorized as depleted under the MMPA. The worldwide population size for all species of *Cephalorhynchus* spp. is unknown. The South American population of Commerson's dolphins is estimated as 31,000 individuals (Dawson, 2009), while the Chilean dolphin population is not as well enumerated, with estimates ranging from 59 to several thousand animals (Jefferson et al., 2008; Dawson, 2009). In New Zealand waters, Hector's dolphins are estimated as 111 animals surrounding the North Island with 7,270 animals found around the South Island (Slooten et al., 2002; Dawson, 2009). Only one population estimate of 6,345 animals exists for Heaviside's dolphins in the Cape Town, South Africa region (Dawson, 2009).

Cephalorhynchus dolphins are found only in the temperate shallow (<200 m [656 ft]), coastal waters of the Southern Hemisphere (Goodall et al., 1988; Goodall, 1994a and 1994b; Sekiguchi et al., 1998; Dawson, 2009). In summer, some species are even observed in the surf zone (Dawson, 2009). Commerson's dolphins occur in two distinct populations, one in the Atlantic waters off southern South America (Chile and Argentina), including the Falkland Islands, and the other in the southern Indian Ocean waters off the Kerguelen Islands (Goodall, 1994a; Dawson, 2009). The Chilean dolphin is restricted to the shallow coastal and inshore (estuaries and rivers) waters of Chile from about 33° to 55°S and occurs year-round throughout this range (Jefferson et al. 2008; Dawson, 2009); this species is frequently observed in very close proximity to the shoreline. Hector's dolphins inhabit shallow waters surrounding New Zealand, occurring commonly along the east and west coasts of South Island but with a much smaller population in the waters of the North Island (Slooten and Dawson, 1994). Hector's dolphins are rarely seen more than 8 km (5 mi) from shore or in waters greater than 75 m (246 ft) deep (Jefferson et al., 2008). Heaviside's dolphins are only found along southwestern Africa from Cape Town, South Africa to Namibia (from 17°S to 34°S), typically occurring in shallow water no deeper than 100 m (328 ft) (Jefferson et al., 2008; Dawson, 2009). There is no evidence of large-scale seasonal movement for Heaviside's dolphins (Dawson, 2009). All of these species prey on benthic and small pelagic fish and squid. The Chilean dolphin is also known to eat crustaceans and algae (Dawson, 2009).

Females produce their first calf between the ages of six to nine. Males achieve sexual maturity between the ages of five to nine. Mating and calving occur in the spring and summer. Gestation lasts about 10-11 months. The calving interval appears to range from two to four years. The oldest Hector's dolphin reported is at least 22 years old (Dawson, 2009).

Commerson's dolphins have been observed swimming at speeds of at least 30 km/hr (16 kts) (Gewalt, 1990), while Heaviside's dolphins swim much more slowly at a typical speed of 1.6 km/hr and a maximum speed of 3.8 km/hr (Davis, 2010). The average foraging dive of the Hector's dolphin ranges from 1 to 1.5 min (Slooten et al., 2002). Heaviside's dolphins also make shallow dives typically less than 2 min to no more than 20 m (66 ft), although they are capable of diving to 104 m and remaining submerged for up to 10 min (Davis, 2010).

There is no direct measurement of the hearing sensitivity of *Cephalorhynchus* dolphins (Ketten, 2000; Thewissen, 2002). Dolphins of this genus produce sound as low as 320 Hz and as high as 150 kHz (Croll et al., 1999). The vocalizations of this genus have been characterized as narrow-band, high frequency, with energy concentrated around 130 kHz and little to no energy below 100 kHz (Au, 1993; Götz et al., 2010). These narrow-band vocalizations of Cephalorhynchus dolphins are relatively low power with a high center frequency (Frankel, 2009). The vocalizations of Commerson's and Hector's dolphins have been studied the most extensively. Members of this genus produce only variations of click and no whistles vocalizations (Frankel, 2009).

The mean peak-to-peak SL for the Commerson's dolphin's vocalizations is 177 dB re 1 μPa @ 1 m (Kyhn et al., 2010). Commerson's dolphins emit varied click vocalizations, and those with a high rate of clicks have been termed "cries" that range up to 5 kHz in frequency with a peak frequency around 1 kHz

(Dziedzic and DeBuffrenil, 1989). Commerson's dolphins emit three click signal-types that have peak frequencies at 1 to 2.4 kHz, 1.6 to 75 kHz, and 116 kHz (Dziedzic and DeBuffrenil, 1989). Kyhn et al. (2010) recently recorded Commerson's dolphin clicks with a peak frequency of 132 kHz and frequencies ranging from about 110 to ~200 kHz. Hector's dolphin emit sounds that are short (140 microsec) with a high peak frequency of 129 kHz (Thorpe and Dawson, 1991). The clicks of Hector's dolphins range from 82 to 135 kHz with a mean peak frequency of 129 kHz and a SL of 177 dB re 1 µPa @ 1 m (Thorpe and Dawson, 1991; Kyhn et al., 2009). Chilean dolphins emit clicks with a peak frequency at 126 kHz and a SL of 177 dB re 1 µPa @ 1 m (Götz et al., 2010). Heaviside's dolphins emit clicks that are <2 to 5 kHz with a dominant frequency of 800 Hz (Watkins et al., 1977).

4.2.36 DALL'S PORPOISE (*PHOCOENOIDES DALLI*)

Dall's porpoise is considered lower risk (conservation dependent) under the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. The total population of Dall's porpoise is unknown but is considered to be one of the most common cetacean species in the central North Pacific (Jefferson et al., 2008; Jefferson, 2009b). There are an estimated 104,000 Dall's porpoises along the Pacific coast of Japan and 554,000 in the Okhotsk Sea (Jefferson et al., 2008). In U.S. waters, there are an estimated 83,400 Dall's porpoises in the Alaskan stock while 48,376 are estimated for the California, Oregon, and Washington stock (Angliss and Allen, 2009; Carretta et al., 2009).

The Dall's porpoise is found exclusively in the North Pacific Ocean and adjacent seas (Bering Sea, Okhotsk Sea, and Sea of Japan) (Jefferson et al., 2008). This oceanic species is primarily found in deep offshore waters from 30°N to 62°N or in areas where deepwater occurs close to shore, but this species has been observed in the inshore waters of Washington, British Columbia, and Alaska (Jefferson et al., 2008). Distribution in most areas is very poorly defined (Jefferson, 2009b). Their primary prey species are schooling fishes, mesopelagic fishes and squids. Invertebrates are occasionally found in their stomachs, but these are rare (Jefferson, 2009b).

Females sexually mature at ages 4-7 and males at ages 3.5-8. Mating and calving are concentrated in the summer and gestation lasts 10-12 months. The duration of lactation is not well known, but likely less than one year (Jefferson, 2009b).

Dall's porpoises are thought to be one of the fastest swimming of the small cetaceans (Croll et al., 1999; Jefferson, 2009b). Average swim speeds are between 2.4 and 21.6 km/hr (1.3 and 11.7 kts) and are dependent on the type of swimming behavior (slow rolling, fast rolling, or rooster-tailing) (Croll et al., 1999). They may reach speeds of 55 km/hr (29.7 kts) for quick bursts (Leatherwood and Reeves, 1983). They are relatively deep divers, diving to 275 m (900 ft) for as long as 8 min (Ridgway, 1986; Hanson et al., 1998).

There is no direct measurement of the hearing sensitivity of Dall's porpoises (Ketten, 2000; Thewissen, 2002). It has been estimated that the reaction threshold of Dall's porpoise for pulses at 20 to 100 kHz is about 116 to 130 dB RL, but higher for pulses shorter than one millisecond or for pulses higher than 100 kHz (Hatakeyama et al., 1994).

Dall's porpoises produce sounds as low as 40 Hz and as high as 160 kHz (Ridgway, 1966; Evans, 1973; Awbrey et al., 1979; Evans and Awbrey, 1984; Hatakeyama and Soeda, 1990; Hatakeyama et al., 1994). They can emit LF clicks in the range of 40 Hz to 12 kHz (Evans, 1973; Awbrey et al., 1979). Narrow band clicks are also produced with energy concentrated around 120 to 130 kHz (Au, 1993). Their maximum peak-to-peak SL is 175 dB (Evans, 1973; Evans and Awbrey, 1984). Dall's porpoise do not whistle very often.

4.2.37 HARBOR PORPOISE (*PHOCOENA PHOCOENA*)

The harbor porpoise is not listed as threatened or endangered under the ESA, is not categorized as depleted under the MMPA, but is classified as vulnerable under IUCN. The global population for the harbor porpoise is unknown. In the Gulf of Maine, there are an estimated 89,054 harbor porpoises (Waring et al., 2009), 27,000 in the Gulf of Saint Lawrence, 28,000 in Iceland waters, 11,000 in Norwegian waters, 36,000 in Kattegat, 268,000 in the North Sea, and 36,000 in the waters around Ireland (Jefferson et al., 2008). There are an estimated 90,407 in Alaskan waters and an estimated 77,980 harbor porpoises occur in the U.S. west coast waters (Angliss and Allen, 2009; Carretta et al., 2009).

Harbor porpoises are found in cold temperate and sub-arctic coastal waters of the northern hemisphere (Gaskin, 1992; Jefferson et al., 1993; Bjørge and Tolley, 2009). They are typically found in waters of about 5 to 16°C (41 to 61°F) with only a small percentage appearing in arctic waters zero to 4°C (32 to 39°F) (Gaskin, 1992). They are most frequently found in coastal waters, but do occur in adjacent offshore shallows and, at times, in deep water (Croll et al., 1999; Gaskin, 1992).

They show seasonal movement in northwestern Europe that may be related to oceanographic changes throughout certain times of the year (Gaskin, 1992; Read and Westgate, 1997; Heimlich-Boran et al., 1998). Although migration patterns have been inferred in harbor porpoise, data suggest that seasonal movements of individuals are discrete and not temporally coordinated migrations (Gaskin, 1992; Read and Westgate, 1997). Three major residential isolated populations exist: 1) the North Pacific; 2) North Atlantic; and 3) the Black Sea (Jefferson et al., 2008; Bjørge and Tolley, 2009). However, there are morphological and genetic data that suggest that different populations may exist within these three regions (Jefferson et al., 2008). For example, there are 10 different stocks in U.S. waters alone, with nine stocks in the North Pacific, and one in the Gulf of Maine in the North Atlantic (Angliss and Allen, 2009; Caretta et al., 2009; Waring et al., 2009). Harbor porpoise feed primarily on small fish, although they also take squid and crustaceans in some areas (Bjørge and Tolley, 2009).

Harbor porpoise become sexually mature between the ages of three and four, with physical maturity occurring at age five. Gestation last approximately 10.5 months and most calving occurs from May to August. Inter-calf interval appears to range from one year in the Atlantic Ocean to two years in the Pacific Ocean. The maximum reported age was 23 years old (Bjørge and Tolley, 2009).

Maximum swim speeds for harbor porpoises range from 16.6 and 22.2 km/hr (9.0 to 12.0 kts) (Gaskin et al., 1974). Dive times range between 0.7 and 1.7 min with a maximum dive duration of 9 min (Westgate et al., 1995). The majority of dives range from 20 to 130 m (65.6 to 426.5 ft), although maximum dive depths have reached 226 m (741.5 ft) (Westgate et al., 1995).

Harbor porpoises can hear frequencies in the range of 100 Hz to 140 kHz (Kastelein et al., 2002; Villadsgaard et al., 2007). Kastelein et al. (2002) determined the best range of hearing for a two-year-old male was 16 to 140 kHz; this harbor porpoise also demonstrated the highest upper frequency hearing of all odontocetes presently known (Kastelein et al., 2002). Harbor porpoises produce click and whistle vocalizations that cover a wide frequency range, from 40 Hz to at least 150 kHz (Verboom and Kastelein, 2007). The click vocalizations consist of four major frequency components: lower frequency component (1.4 to 2.5 kHz) of high amplitude that are may be used for long-range detection; two middle frequency components consisting of a low amplitude (30 to 60 kHz) and a broadband component (10 to 100 kHz); and a higher frequency component (110 to 150 kHz) that is used for bearing and classification of objects (Verboom and Kastelein, 1995; Verboom and Kastelein, 2007). Harbor porpoise's lowest frequency vocalization, from 40 to 600 Hz, are whistles (Frankel, 2009). Vocalization peak frequencies are similar for wild and captive harbor porpoises, with the peak frequencies reported to range from 129 to 145 kHz and 128 to 135 kHz, respectively (Villadsgaard et al., 2007). Maximum SLs vary, apparently, between captive and wild dolphins, with maximum SLs of 172 dB re 1 µPa at 1 m in captive dolphins but range from 178 to 205 dB re 1 µPa at 1 m in wild dolphins (Villadsgaard et al., 2007). Variations in click trains apparently represent different functions based on the frequency ranges associated with each activity.

4.2.38 SPECTACLED PORPOISE (*PHOCOENA DIOPTRICA*)

The spectacled porpoise is one of the world's most poorly known cetaceans. This species is classified as data deficient by the IUCN but is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. There is no information about the abundance of this species (Goodall, 2009b). There are also no data on diving, swim speeds, hearing, or vocalizations. Feeding has not been observed, although the few stomach contents obtained included fish otoliths, squid beaks and stomatopods. Little data on life history are available, with no estimates of pregnancy rate, gestation length or nursing period (Goodall 2009b).

Spectacled porpoises are circumpolar in occurrence and are found only in the cool temperate, sub-Antarctic, and Antarctic waters of the southern hemisphere (Goodall, 2009b). The species is known from Brazil to Argentina in offshore waters and around offshore islands including Tierra del Fuego, the Falklands (Malvinas), and South Georgia in the southwestern South Atlantic; Auckland and Macquarie in the southwestern Pacific; and Heard and Kergulen in the southern Indian Ocean (Goodall, 2009b). Sightings are most often documented in oceanic waters ranging from 4.9 °to 6.2°C (40.8° to 43°F), but this species has also been sighted in nearshore waters and even in river channels (Goodall, 2009b).

4.3 PINNIPEDS

Twenty-four pinnipeds species may occur in the potential operating areas for SURTASS LFA sonar (Table 4). Eared or otariid seals are distinguished by swimming with their foreflippers and moving on all fours on land. In contrast, true or phocid seals swim with undulating motions of the rear flippers and have a type of crawling motion on land. Otariids have ear flaps (pinnae) that are similar to carnivore ears. Phocid ears have no external features and are more water-adapted. Otariids have also retained their fur coats (Berta, 2009), whereas phocids and walruses have lost much of their fur and instead have thick layers of blubber. Many pinniped populations today have been reduced by commercial exploitation, incidental mortality, disease, predation, and habitat destruction (Bowen et al., 2009). Pinnipeds were hunted for their furs, blubber, hides, and organs. Some stocks have begun to recover. However, populations of species such as the northern fur seal and the Steller sea lion continue to decline (Gentry, 2009).

Hearing capabilities and sound production are highly developed in all pinniped species studied to date. Pinnipeds are assumed to rely heavily on sound and hearing for breeding activities and social interactions (Schusterman, 1978; Berta, 2009; Frankel, 2009). They are able to hear and produce sounds in both air and water but have different functional hearing ranges in air and water. Their air-borne vocalizations include grunts, snorts, and barks, which are often used as aggression or warning signals, or to communicate in the context of breeding and rearing young. Under water, pinnipeds can vocalize using whistles, trills, clicks, bleats, chirps, and buzzes as well as lyrical calls (Schusterman, 1978; Berta, 2009; Frankel, 2009). Sensitivity to sounds at frequencies above 1 kHz has been well documented. The few studies that have been conducted on the sensitivity to low frequency have shown some pinniped sensitivity to LF sound.

4.3.1 OTARIIDS

4.3.1.1 South American fur seal (*Arctocephalus australis*)

The South American fur seal is listed as a least concern (lower risk) species under the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. The abundance of the Southern fur seal and its subspecies, which only occurs in the Falkland Islands, is not well known. The South American fur seal's coastal and offshore populations are currently estimated at 235,000 to 285,000 animals (Arnould, 2009).

South American fur seals range from central Peru to the Straits of Magellan in the southern Pacific Ocean and from southern Brazil to Uruguay in the southern Atlantic Ocean (Jefferson et al., 2008). Most colonies of South American fur seals are located on offshore islands except in Peru, where the colonies are located on the mainland (Arnould, 2009). Males are sometimes seen seasonally up to 600 km (324 nmi) offshore (Jefferson et al., 2008). These fur seals are believed to occur predominantly in continental shelf and continental slope waters. South American fur seals feed on a wide variety of prey, including fish, cephalopods, crustaceans, penguins and seabirds (Arnould, 2009). The minimum age for first parturition is three years (Wickens and York, 1997).

South American fur seals have been recorded diving to mean water depths of 34 m and a maximum depth of 170 m with mean and maximum dive durations of 2.5 and 7.1 min, respectively (Riedman, 1990). Thompson et al. (2003) found that satellite tagged South American fur seals foraged in waters 50 to about 600 m deep and swam at an average speed of 1.5 m/sec (2.9 kts).

There is no direct measurement of the hearing sensitivity of South American fur seals. The primary calls made by South American fur seals are whimpers, barks, growls, whines, and moans. There is a strong vocal connection between mother and pups. The female South American fur seal has a call with a frequency between 1 and 5,870 Hz. The pups have a higher frequency call, between 1 and 6,080 Hz (Phillips and Stirling, 2000).

4.3.1.2 New Zealand fur seal (*Arctocephalus forsteri*)

The New Zealand fur seal is listed as a least concern (lower risk) species under the IUCN, is not listed as threatened or endangered under the ESA, and is not categorized as depleted under the MMPA. The global population estimate is 135,000 seals, with 35,000 found in Australia (Jefferson et al., 2008). The New Zealand fur seal is a temperate species having two genetically distinct populations. One population is around both the North and South islands of New Zealand, with the larger population around South Island. The second population is found on the coast of southern and western Australia (Jefferson et al., 2008). Their principal breeding colonies occur at South Island and Stewart Island along the coast of western and southern Australia and off Tasmania at Maatsuyker Island. Breeding colonies also exist at the subantarctic Chatham, Campbell, Antipodes, Bounty, Aukland, and Macquarie islands, and at Kangaroo Island off southern Australia (Reeves et al., 2002). The New Zealand fur seal prefers rocky and windy habitats that are protected from the sun for breeding (Jefferson et al., 2008).

New Zealand fur seals forage at night, with varying dive depths and times depending on age and sex. New Zealand fur seals feed on a wide variety of prey, including fish, cephalopods, crustaceans, penguins and seabirds (Arnould, 2009). New Zealand fur seal pups were recorded at a maximum dive depth of 44 m (144 ft) for 3.3 min (Baylis et al., 2005). Adult females recorded a maximum dive depth of 312 m (1,024 ft), and a maximum dive time of 9.3 min off the southern coast of Australia (Page et al., 2005). Adult male New Zealand fur seals had a maximum dive of more than 380 m (1,247 ft), and a maximum dive time of 14.8 min (Page et al., 2005). No available swim speed data are available.

Females reached sexual maturity between four and six years of age, while males matured between five and nine years. The maximum age observed was 22 years old (Dickie and Dawson, 2003).

In-air vocalizations of the New Zealand fur seal have been described as full-threat calls. These individually distinctive vocalizations are emitted by males during the breeding season (Stirling, 1971). New Zealand fur seals also produce barks, whimpers, growls, whines, and moans (Page et al., 2002). The hearing capabilities of this species are unknown, and no information exists on frequency of vocalizations.

4.3.1.3 Galapagos fur seal (*Arctocephalus galapagoensis*)

The Galapagos fur seal is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA; it is listed as endangered under the IUCN, however. The population is estimated currently as 12,000 individuals although estimates from the late 1989s were about 40,000 animals (Jefferson et al., 2008; Arnould, 2009).

Galapagos fur seals are nonmigratory. Their distributional range is limited to the equatorial region throughout the Galapagos Islands (Arnould, 2009). These seals haul out on rock shorelines with most colonies located in the western and northern parts of the Galapagos Archipelago and occasionally come ashore on the mainland Ecuadorian coast (Jefferson et al., 2008). Galapagos fur seals feed on a wide variety of prey, including fish, cephalopods, crustaceans, penguins and seabirds (Arnould, 2009). The minimum age for first birth is five years (Wickens and York, 1997).

The diving habits of Galapagos fur seals are dependent on age. Six-month-old seals have been recorded to dive up to 6 m (20 ft) for 50 sec. Yearlings dive to 47 m (150 ft) for 2.5 min, and 18-month-old juveniles dive up to 61 m (200 ft) for 3 min (Stewart, 2009). The longest and deepest dive recorded by a Galapagos fur seal was 5 min at a depth of 115 m (377 ft) (Jefferson et al., 2008). Galapagos fur seals swim at about 1.6 m/sec (3.1 kts) (Williams, 2009). No information is available on the hearing abilities of this species. Galapagos fur seals produce low frequency long growls (<1 kHz) and short broadband grunts that are less than 2 kHz (Frankel, 2009).

4.3.1.4 Juan Fernandez fur seal (*Arctocephalus philippii)*

The Juan Fernandez fur seal is classified as near threatened under the IUCN but is not listed under the ESA nor is it categorized as depleted under the MMPA. The species was believed to have been hunted to extinction until 1965 when a small remnant population was located. The population is currently estimated at 18,000 seals (Arnould, 2009).

Juan Fernandez fur seals are restricted to the Juan Fernandez island group off the coast of north central Chile (Jefferson et al., 2008). Currently this seal occupies four major breeding colonies and hauls out on rocky shorelines (Arnould, 2009). Juan Fernandez fur seals feed on a wide variety of prey, including fish, cephalopods, crustaceans, penguins and seabirds (Arnould, 2009).

Juan Fernandez fur seals can travel an average distance of 653 km (353 nmi) from breeding grounds to feeding grounds, where they forage at depths between 10 and 90 m (35 and 295 ft) (Jefferson et al., 2008). Maximum dive depths for this seal range from 50 to 90 m (163 to 295 ft), with most dives less than 10 m (33 ft) (Francis et al., 1998). The most common dive times lasted less than 1 min, with a maximum dive time of 6 min (Jefferson et al., 2008). Most dives occur at night (Francis et al., 1998). No swim speed information is available.

There is no information available on the hearing abilities of the Juan Fernandez fur seal. The Juan Fernandez fur seal has been recorded producing clicks with a frequency of 0.1 to 0.2 kHz (Richardson et al., 1995). Other information about this species' sound production is not available.

4.3.1.5 South African fur seal (*Arctocephalus pusillus pusillus*)

South African or Cape fur seals are listed as a species of least concern (lower risk) by the IUCN, are not listed as threatened or endangered under the ESA, and are not categorized as depleted under the MMPA. The most recent population census in 2004 indicates that the population of South African fur seals is stable at an estimated 2 million animals (Arnould, 2009).

South African fur seals occur along the southern African coast from South Africa to Angola (Jefferson et al., 2008). Breeding occurs at 25 colonies along the coasts of South Africa and Namibia, including four mainland colonies (Arnould, 2009). The mean age of reproductive females is 9.4 years (Wickens and York, 1997).

South African fur seals feed within approximately 5 km (2.7 nmi) of land and are believed to be nonmigratory. South African fur seals feed on a wide variety of prey, including fish, cephalopods, crustaceans, penguins and seabirds (Arnould, 2009).Females fur seals dove to an average depth and duration of 45 m (ft) for 2.1 min with the maximum depth and duration of 204 m (669 ft) and 7.5 min (Kooyman and Gentry, 1986). No swim speed data are available for this species. There is also no information available on the hearing abilities or sound production of the South African fur seal.

4.3.1.6 Australian fur seal (*Arctocephalus pusillus doriferus*)

Australian fur seals are listed as a species of least concern (lower risk) by the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. Most of their breeding and haulout sites are protected by Australian federal, state, and territorial laws. Currently, the population of Australian fur seals is estimated at 92,000 animals (Arnould, 2009).

Australian fur seals are believed to be non-migratory. They are found along the southern and southwestern coast of Australia from just east of Kangaroo Island to Houtman Albrolhos in Western Australia (Jefferson et al., 2008). Breeding colonies are restricted to 10 islands in Bass Strait (Arnould, 2009). Australian fur seals prefer rocky habitats for hauling out and breeding (Jefferson et al., 2008).

Australian fur seals forage at shallow depths along the continental shelf and continental slope waters (Jefferson et al., 2008). Australians fur seals feed on a wide variety of benthic prey, including fish, cephalopods, crustaceans (Arnould, 2009). An average dive depth and duration of a male off the coast of Australia was 14 m (46 ft) and 2.3 min; the maximum dive depth and duration that were recorded was 102 m (335 ft) and 6.8 min (Hindell and Pemberton, 1997). No swim speed data are available for this species.

Australian fur seals have a mid-gestation pregnancy rate of 85%, although it drops 53% in females with offspring, suggesting that a large number of late-gestation abortions occur (Gibbens *et al.*, 2010). The reproductive rate is dependent upon oceanographic conditions, with poor foraging leading to seasonal reproductive failures (Gibbens and Arnould, 2009). The minimum age of parturition is four years (Wickens and York, 1997).

There is no information available on the hearing abilities for the Australian fur seal. Vocalizations made by Australian fur seals are not well known. These fur seals produce a variety of sounds such as barks, mother-pup calls, growls, and submissive calls. Tripovich et al. (2008) found that pups had a maximum energy of 1,300 Hz, while yearlings had a maximum energy of 800 Hz. Females had an average call frequency of 262 ± 35 Hz (Tripovich et al., 2008).

4.3.1.7 Guadalupe fur seal (*Arctocephalus townsendi*)

The Guadalupe fur seal is currently classified as threatened under ESA, depleted throughout its range under the MMPA, CITES protected, and considered a near-threatened species under the IUCN. The current worldwide population size for this species is unknown. The most recent population estimate, 7,408 seals, was estimated in 1993 (Caretta et al., 2009).

The distribution of Guadalupe fur seals is centered on Guadalupe Island, Mexico with most breeding occurring there, but recently pups have been born at a former rookery in the San Benitos Islands, Mexico and on San Miguel Island, California (Jefferson et al., 2008). They prefer either a rocky habitat or volcanic caves. Guadalupe fur seals feed on a wide variety of prey, including fish, cephalopods, crustaceans, and seabirds (Arnould, 2009).

For the Guadalupe fur seal, swim speeds range from 1.8 to 2.0 m/sec (3.4 to 3.9 kts) (Gallo-Reynoso, 1994). Guadalupe fur seals are shallow divers, foraging within the upper 30 m (100 ft) of the water column and diving to a mean water depth of 16.9 m (56 ft) for mean a duration of 2.6 min (Gallo-Reynoso, 1994).

There is no direct measurement of auditory threshold for the hearing sensitivity of Guadalupe fur seals (Thewissen, 2002). The only available data on the sound production of this species are that males produce airborne territorial calls during the breeding season (Pierson, 1987).

4.3.1.8 Subantarctic fur seal (*Arctocephalus tropicalis*)

Subantarctic fur seals are considered a least concern (lower risk) species under the IUCN and is not listed under the ESA nor is it categorized as depleted under the MMPA. The current population of this widely dispersed fur seal is more than 310,000 animals (Arnould, 2009). More than 200,000 seals occur at Gough Island in the South Atlantic with good sized colonies occurring in the southern Indian Ocean at Prince Edward Island with 75,000 animals and Amsterdam Island with 50,000 (Arnould, 2009).

This fur seal species ranges throughout the southern hemisphere from the Antarctic Polar Front northward to southern Africa, Australia, Madagascar, and the South Island of New Zealand with rare vagrants reported from as far north as Brazil (Jefferson et al., 2008). Subantarctic fur seals feed on a wide variety of prey, including fish, cephalopods, crustaceans, and seabirds (Arnould, 2009). Breeding occurs north of the Antarctic Convergence in the South Atlantic and Indian Oceans, mostly on the islands of Amsterdam, Saint Paul, Crozet, Gough, Marion, Prince Edward, and Macquarie (Jefferson et al., 2008).

Females began ovulating at age four and became sexually mature at six years old. Gestation period has been measured at 360 days, from ovulation to birth. Most females appear to give birth each year and may enter reproductive senescence at about age 13 (Bester, 1995).

In the summer, subantarctic fur seals commonly dive to water depths averaging 16.6 to 19 m (ft) for 1 min, while dives in the winter seals dive to an average depth of 29 m for 1.5 min; maximum dive depths and durations have been recorded at 208 m (682 ft) and 6.5 min (Jefferson et al., 2008). No swim speed data are available.

There is no information available on subantarctic fur seal hearing. Males make three kinds of in-air vocalizations, including barks for territorial status, guttural growls, or puffs to state territorial boundaries, and high-intensity calls to warn or challenge other males, while females make a loud, tonal honk to call their pups. There is no direct information on frequency of calls of the subantarctic fur seal.

4.3.1.9 Northern fur seal (*Callorhinus ursinus*)

Northern fur seals are currently classified as a vulnerable species under IUCN, depleted under the MMPA, but are not listed as threatened or endangered under the ESA. There is no current global population estimate available for this species. The eastern Pacific stock is estimated to be 665,550 seals (Angliss and Allen, 2009). The San Miguel Island stock is estimated to be 9,424 seals (Carretta et al., 2009).

Northern fur seals are widely distributed across the North Pacific, and are generally associated with the continental shelf break. They range from northern Baja California, north to the Bering Sea, and across the Pacific to the Sea of Okhotsk and the Sea of Japan (Jefferson et al., 2008). Northern fur seals predate on a wide variety of species, including fish, cephalopods, crustaceans and birds (Gentry, 2009). Other breeding sites include the Pribilof Islands, Robben Island in the Sea of Okhotsk, and San Miguel Island off California (Gentry, 2009b). Pups leave land after about four months and must learn to hunt while migrating. The migration routes and distribution of pups is difficult to assess because they are small and difficult to recapture, but a known migration route exists through the Aleutian passes into the Pacific Ocean in November.

Northern fur seals are sexually dimorphic with males up to 4.5 times as large as females. Males defend territories on the pupping grounds. Females appear to choose a pupping site without considering the male defending the territory. Sexual maturity is achieved at an age of 3-5 years old. Females produce one calf per year up to about age 22. Males become socially mature, i.e. able to hold a territory, at ages of 8 to 9 (Gentry, 2009).

Routine swim speeds during migration for this species are 2.85 km/hr (1.54 kts), and during foraging, swim speeds averaged between 0.89 and 2.28 km/hr (0.48 to 1.23 kts) (Ream et al., 2005). Maximum recorded dive depths of breeding females are 207 m (680 ft) in the Bering Sea and 230 m (755 ft) off southern California (Goebel, 1998). The average dive duration is near 2.6 min. Juvenile fur seals in the Bering Sea had an average dive time of 1.24±0.09 min, and an average depth of 17.5 m (57.4 ft) (Sterling and Ream, 2004). The maximum depth for juvenile fur seals was 175 m (574 ft) (Sterling and Ream, 2004).

The northern fur seal can hear sounds in the range of 500 Hz to 40 kHz (Moore and Schusterman, 1987; Babushina et al., 1991). Their hearing is most sensitive between 2 and 29 kHz (Gentry, 2009b). Northern fur seals are known to produce clicks and high-frequency sounds under water (Frankel, 2009). Estimated source levels and frequency ranges are unknown. There are no available data regarding frequency of vocalizations.

4.3.1.10 Steller sea lion (*Eumetopias jubatus*)

The Steller sea lion is also known as the northern sea lion. The species is classified as an endangered species under IUCN. The Western population is listed as endangered under the ESA, and the Eastern population is listed as threatened under the ESA. The Steller sea lion is considered depleted throughout its range under the MMPA. The worldwide population size for this species is estimated to be 100,000 (Loughlin, 2009). The eastern U.S. stock (east of Cape Suckling, Alaska) in the Pacific is estimated to be between 45,095 and 55,832. The western U.S. stock (west of Cape Suckling, Alaska) in the Pacific is estimated to be 44,780 (Angliss and Allen, 2009). Critical habitats for this species are designated under the ESA in three geographic locations in the North Pacific Ocean, Gulf of Alaska, and Bering Sea including: 1) Alaska rookeries, haulouts, and associated areas; 2) California and Oregon rookeries and associated areas; and 3) special aquatic areas in Alaska (Shelikof Strait area, Bogoslof area, and Seguam Pass area) (50 CFR § 226.202).

Steller sea lions are found in temperate or sub-polar waters and are widely distributed throughout the North Pacific from Japan to central California, and in the southern Bering Sea. Steller sea lions eat a variety of fish and invertebrates species, and specific prey items vary regionally (Loughlin, 2009). Breeding generally occurs during May through June in California, Alaska, and British Columbia. The northernmost rookery is found at Seal Rocks in Prince William Sound, Alaska, and the southernmost rookery is found at Ano Nuevo Island in California (Loughlin, 2009). They may haul out on sea ice in the Bering Sea and the Sea of Okhotsk, which is unusual for otariids.

Females reach sexual maturity between the ages of 3 and 8, while males socially mature at about age nine. Males establish territories in May before the females arrive. Births begin in late May and continue through early July. Females typically breed two weeks after parturition and typically have a pup every year until they reach age 22. Males rarely live past their mid-teens while females can live into their thirties (Loughlin, 2009).

Female Steller sea lions on foraging trips during the breeding season had a maximum dive depth of 236 m (774 ft), and the longest dive was greater than 16 min. The average dive depth for foraging females was 29.6 m (97.1 ft). Average dive time was recorded at 1.8 min (Rehberg et al., 2009). Swim speeds of this species are not known.

Kastelein et al. (2005) studied the differences between male and female Steller sea lion hearing and vocalizations; female and pup in-air vocalizations are described as bellows and bleats while underwater vocalizations are described as belches, barks, and clicks. Their study was conducted because Steller sea lion hearing may not resemble that of other tested otariids and because there are large size differences between males and females which mean there could be differences in the size structure of hearing organs and therefore differences in hearing sensitivities. The underwater audiogram of the male showed his maximum hearing sensitivity at 77 dB RL at 1 kHz, while the range of his best hearing, at 10 dB from the maximum sensitivity, was between 1 and 16 kHz and the average pre-stimulus responses occurred at low frequency signals (Kastelein et al., 2005). Female Steller's maximum hearing sensitivity, at 73 dB RL, occurred at 25 kHz (Kastelein et al., 2005). The frequency range of underwater vocalizations was not shown and properly studied in this case because the equipment used could only record sounds audible up to 20 kHz. However, the maximum underwater hearing threshold from this study overlaps with the frequency range of the underwater vocalizations that were able to be recorded, and it was stated by the authors that the Steller sea lions in this study showed signs that they can hear the social calls of the killer whale (*Orcinus orca*), one of their main predators. The killer whale's echolocations clicks are between 500 Hz and 35 kHz, which is partially in the auditory range of the Steller sea lions in this study. This study also showed that low frequency sounds are audible (Kastelein et al., 2005).

Steller sea lion underwater sounds have been described as clicks and growls (Poulter, 1968; Frankel, 2009). Males produce a low frequency roar when courting females or when signaling threats to other males. Females vocalize when communicating with pups and with other sea lions. Pups make a bleating cry and their voices deepen with age (Loughlin, 2009). No available data exist on seasonal or geographical variation in the sound production of this species.

4.3.1.11 California sea lion (*Zalophus californianus*)

California sea lions are listed as a least concern (lower risk) species under the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. The population size for this species is estimated to be 238,000 seals (Carretta et al., 2009). California sea lions are common along the Pacific coast of the United States and Mexico, ranging from the Tres Marias Islands, Mexico, to the Gulf of Alaska, although California sea lions are rare farther north than Vancouver, British Columbia (Jefferson et al., 2008, Heath and Perrin, 2009). The principal breeding areas for the California sea lion are the Channel Islands off southern California, the islands off the coast of Baja California, Mexico, and in the Gulf of California. California sea lions eat a wide variety of prey including fish and squids. The diet is largely determined by the relative abundance of the different prey species (Heath and Perrin, 2009).

Sexual maturity occurs at about 4-5 years of age, although males are not able to hold territories until several years later. The breeding season lasts for most of the year with births occurring from June to March. Lactation typically lasts 10-12 months. Females typically mate three weeks after giving birth. Maximum lifespan is estimated at 15-24 years (Heath and Perrin, 2009).

Lactating females have recorded dives to 247 m (810 ft), lasting over 10 min. Most foraging dives are shallower than 80 m (262 ft) and last less than 3 min (Jefferson et al., 2008). There is no swim speed information available for the California sea lion.

California sea lions can hear sounds in the range of 75 to 64 kHz. Low frequency amphibious hearing tests suggest that California sea lions are relatively insensitive to most anthropogenic sound in the water, as sea lions have a higher threshold (116.3 to 119.4 dB RL) at frequencies of 100 Hz (Kastak and Schusterman, 1998). Underwater sounds produced by California sea lions include barks, clicks, buzzes, and whinnies. Barks are less than 8 kHz with dominant frequencies below 3.5 kHz; the whinny call is typically between 1 and 3 kHz, and the clicks have dominant frequencies between 500 Hz and 4 kHz (Schusterman, 1967). Buzzing sounds are generally from less than 1 kHz to 4 kHz, with the dominant frequencies occurring below 1 kHz (Schusterman, 1967).

4.3.1.12 Galapagos sea lion (*Zalophus wollebaeki*)

Galapagos sea lions are not listed as threatened or endangered under the ESA, not categorized as depleted under the MMPA, but are classified as endangered under the IUCN. The current population is estimated to be between 20,000 and 50,000 seals (Jefferson et al., 2008). Galapagos sea lions are an equatorial species closely related to California sea lions. Their range is restricted to the Galapagos Islands with a small colony on La Plata Island off the coast of Ecuador. Occasionally, vagrants can be seen along the Ecuador and Columbia coasts, particularly around Isla del Coco, Costa Rica, and Isla del Gorgona. Galapagos sea lions specialize on sardines, although they can alter their diet in response to El Niño events. (Heath and Perrin, 2009)

Galapagos sea lions are a nonmigratory species that forage within a few kilometers of the coast, feeding both during the day and night. Their dives average 91.8 ± 35.2 m (301.2 ± 115.5 ft) but have been known to reach as deep as 149 m (489 ft). Average dive duration is 4.0 ± 0.9 min (Villegas-Amtmann et al., 2008). Swim speeds are typically about 2 m/sec (3.9 kts) (Williams, 2009). There is no information available on the hearing abilities or sound production of this species.

4.3.1.13 Australian sea lion (*Neophoca cinerea*)

The Australian sea lion is listed as endangered under the IUCN due to its small, genetically fragmented population, which appears to be declining at some colonies. However, this species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. Additionally, most major colonies are at risk of extinction from fishery bycatch. The Seal Bay area has been designated as a conservation park for these sea lions (Ling, 2009). The total population of Australian sea lions has most recently been estimated as 9,794 animals. Australian sea lions feed on cephalopods, crustaceans and fish (Ling, 2009).

The Australian sea lion is a temperate species found only along the south and west coast of Australia (Jefferson et al., 2008). About 73 colonies exist, with 47 in southern Australia and 26 in western Australia, although only six colonies produce are large enough to produce more than 100 pups per season (Ling, 2009). The largest breeding colonies are located on Purdie Islands, Dangerous Reef, Seal Bay, and The Pages (Ling, 2009).

Australian sea lions have an unusual life history, including an 18 month reproductive cycle and a five month long pupping season. Gestation last 14 months after implantation, and mother may nurse pups until the next pup is born. Mating takes place approximately one week after birth (Ling, 2009).

Females and juveniles do not typically migrate. Australian sea lions are fast, powerful swimmers (Ling, 2009). Female Australian sea lions dive to an average depth and duration of 42 to 83 m (ft) and 2.2 to 4.1 min, with maximum dives ranging from 60 to 105 m (344 ft) (Jefferson et al., 2008). The average duration of all foraging dives was 3.3 min, with a maximum dive time of 8.3 min (Costa and Gales, 2003).

There is no information available on the hearing abilities or sound production of this species. However, females have reported to emit low-frequency pup-attraction calls, while pups emit higher frequency calls (Richardson, et al., 1995).

4.3.1.14 New Zealand sea lion (*Phocarctos hookeri*)

The New Zealand sea lion, also known as Hooker's sea lion, is listed under the IUCN as vulnerable; this species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. With an estimated abundance of 12,500 individuals, this sea lion's population is considered stable (Gales, 2009). This rarely occurring sea lion is endemic to New Zealand waters and has one of the most restricted ranges of all pinnipeds. They feed on fish, cephalopods and crustaceans (Gales, 2009). This sea lion occur in two geographically isolated and genetically distinct populations around New Zealand and southern and western coast of Australia (Jefferson et al., 2008). Although once found in all the New Zealand waters, the current breeding range of the New Zealand sea lion is limited to two groups of subantarctic islands, the Auckland and Campbell Islands, with pups occasionally born along the shore of the South Island; approximately 86% of New Zealand sea lion pups are born in the Auckland Islands (Gales, 2009).

Females become sexually mature at age three and produce their first pup the following year. Males mature sexually at five years of age, but are not able to hold territories until they are 8-10 years old. Males arrive on the rookeries in later November to establish territories and the females arrive in December and form harems of up to 25 females. Females give birth soon after arriving on the rookery. The pupping season lasts about 35 days and the animals have dispersed by the end of January. Females live to about 28 years old (Gales, 2009).

New Zealand sea lions are among the deepest and longest divers of the otariids, diving to a mean water depth of 123 m (404 ft) with average dive duration of 3.9 min (Gales, 2009). The maximum foraging dive depth recorded for a lactating female was 550 m (1,804 ft) and the longest dive time was 11.5 min (Costa and Gales, 2003). Swim speeds are about 1.3 m/sec (2.5 kts) (Williams, 2009).

There is no information available on the hearing abilities of this species. New Zealand sea lions all bark and produce clicks under water (Poulter, 1968).There is no direct data on frequency of vocalizations.

4.3.1.15 South American sea lion (*Otaria flavescens*)

South American sea lions are listed as a least concern (lower risk) species under the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. The current total population is estimated to be between 200,000 and 300,000 seals (Jefferson et al., 2008), with 110,000 sea lions occurring along the southwestern Atlantic coastal areas (Cappozzo and Perrin, 2009).

South American sea lions are nearly continuously distributed along most of South America from southern Brazil to northern Peru, including the Falkland Islands and Tierra del Fuego (Jefferson et al., 2008). This sea lion is principally concentrated in central and southern Patagonia, where more than 53 breeding colonies are found (Cappozzo and Perrin, 2009). The South American sea lion is primarily found in continental shelf and continental slope waters (Jefferson et al., 2008). South American sea lions primarily prey on benthic and demersal species, primarily fish and squids. The diet reflects local concentrations of prey species. They are flexible foragers and can add other invertebrates or penguins to their diet based on local availability (Cappozzo and Perrin, 2009).

South American sea lions are sexually dimorphic with the males being distinctly larger. Males maintain territories on the mating haulout area and the mating system is female-defense polygyny. Females become sexually mature at age five, while males mature at age six. The breeding and pupping season begins in mid-December and lasts until February. Lactation typically lasts 8-10 months (Cappozzo and Perrin, 2009).

Campagna et al. (2001) found the dives of South American sea lions to be short, typically less than 4 min, and shallow, from 2 to 30 m (6.6 to 98 ft). The maximum depth to which a South American sea lion has been recorded diving is 175 m (574 ft) and the maximum dive duration of 7.7 min (Werner and Campagna, 1995). Median swim speed recorded for this species was 2.7 km/hr (1.46 kt) (Campagna et al., 2001).

There is no information available on the hearing abilities of the South American sea lion. South American sea lions produce most vocalizations during their breeding season, with airborne calls by males characterized as high-pitched, directional calls, barks, growls, and grunts while females exhibited grunts and specific calls with their pups that were long duration and harmonically rich (Ferńandez-Juricic et al., 1999). Frequencies of the measured South American sea lion vocalizations ranged widely from 240 to 2240 Hz (Ferńandez-Juricic et al., 1999).

4.3.2 PHOCIDS

4.3.2.1 Mediterranean monk seal (*Monachus monachus)*

Mediterranean monk seals are listed as endangered under the ESA, depleted throughout their ranged under the MMPA, critically endangered under IUCN, and protected under CITES. The worldwide population size for this species is estimated to be between 350 and 450 animals (Jefferson et al., 2008), with the largest population of 250-300 seals found in the eastern Mediterranean (Gilmartin and Forcada, 2009). The two breeding populations at Cap Blanc, with about 120 seals, and in the Desertas Islands of the Madeira Islands group, with about 25 seals, remain. Monk seals eat a wide variety of fish, octopus, squid and lobster (Gilmartin and Forcada, 2009).

Although severely contracted from its former range, Mediterranean monk seals are currently distributed throughout the Mediterranean, Black, Ionian, and Aegean Seas and the Sea of Marmara, and in the eastern North Atlantic Ocean from the Strait of Gibraltar south to Mauritania and the Madeira Island (Jefferson et al., 2008; Gilmartin and Forcada, 2009). There is no evidence of seasonal movement for this species. Mediterranean monk seals exhibit high site fidelity and thus only occupy part of their suitable range and habitat (Gilmartin and Forcada, 2009).

Monk seals are an aquatic mating species and have a protracted reproductive season. Female Mediterranean monk seals are sexually mature at three years of age, although this can be delayed in areas with poor foraging. They give birth year round with a peak from summer to early winter. The typical birthing interval is one year, although individuals may rest a year Gilmartin and Forcada, 2009).

No direct data are available on swim speed. Dendrinos et al. (2007) reported a maximum water depth of 123 m (404 ft) for a rehabilitated monk seal that was tagged and released in the Mediterranean Sea. Gazo and Aguilar (2005), however, described the maximum dive depth and duration as 78 m (256 ft) and 15 min while the mean dive depth and duration of the dives of a lactating female were 30 m (98 ft) and 5 min (Gazo and Aguilar, 2005). Kiraç et al. (2002) recorded mean dive durations of 6.4 min for adults and 6.8 min for juveniles.

Although no data are available on underwater hearing or vocalizations of Mediterranean monk seals, some limited data are available for in-air vocalizations of Hawaiian monk seals. Recorded in-air vocalizations of Hawaiian monk seals consist of what has been referred to as a liquid bubble sound (100 to 400 Hz), a guttural expiration (about 800 Hz) produced during short-distance agonistic encounters, a roar (<800 Hz) for long-distance threats, a belch-cough made by males when patrolling (<1 kHz), and sneeze/snorts/coughs of variable frequencies that are <4 kHz (Miller and Job, 1992).

4.3.2.2 Hawaiian monk seal (*Monachus schauinslandi*)

Hawaiian monk seals are listed as endangered under the ESA, depleted throughout their range under the MMPA, endangered under IUCN, and protected under CITES. The best available population estimate for this species is 1,208 individuals (Carretta et al., 2009). Critical habitats are designated under the ESA in the northwestern Hawaiian Islands for all beach areas, sand spits and islets including all beach crest vegetation to its deepest extent inland, lagoon waters, inner reef waters, and oceanic waters to a depth of 20 fathoms (37 m) around Kure Atoll, Midway Island, Pearl and Hermes Reef, Lisianski Island, Laysan Island, Maro Reef, Gardner Pinnacles, French Frigate Shoals, Necker Island, and Nihoa Island. (50 CFR § 226.201).

Hawaiian monk seals are found almost exclusively in the uninhabited Northwestern Hawaiian Islands and are found to a lesser extent in the main Hawaiian Islands, particularly on Kauai, with rare sightings on Johnson Atoll, Wake Island, and Palmyra Atoll (Jefferson et al., 2008; Gilmartin and Forcada, 2009). Pups have been born on the islands of Maui, Kauai, Oahu, and Molokai. Hawaiian monk seals exhibit high site fidelity to their natal island. Monk seals eat a wide variety of fish, octopus, squid and lobster (Gilmartin and Forcada, 2009).

Monk seals are an aquatic mating species and have a protracted reproductive season. Female Hawaiian monk seals are sexually mature at four years of age, although this can be delayed in areas with poor foraging. They typically give birth from February to August with a peak in April to June. Hawaiian females show an average of 381 day between births. Especially at colonies with skewed sex-ratios, males may mob a female, in an attempt to gain a copulation. This behavior can lead to injury or death of the female (Gilmartin and Forcada, 2009).

No swim speed data are available. This species commonly dive to depths of less than 100 m (328 ft) but have been recorded diving down to depths of 300 to 500 m (984 to 1,640 ft) (Parrish et al., 2002). The Hawaiian monk seal can also dive for up to 20 min, and perhaps longer (Parrish et al., 2002). Routine dives range from 3 to 6 min in principally shallow water depths from 10 to 40 m (33 to 131 ft) (Stewart, 2009).

Only one audiogram has been recorded for the Hawaiian monk seal, which indicated relatively poor hearing sensitivity, a narrow range of best hearing sensitivity (12 to 28 kHz and 60 to 70 kHz), and a relatively low upper frequency limit (Thomas et al., 1990a). However, this audiogram was obtained from a single, untrained individual whose hearing curve suggested that its responses may have been affected by disease or age (Reeves et al. 2001). Their most sensitive hearing is at 12 to 28 kHz, which is a narrower range compared to other phocids. Above 30 kHz, their hearing sensitivity drops markedly (Thomas et al., 1990). No underwater sound production has been reported. Recorded in-air vocalizations of Hawaiian monk seals consist of what has been referred to as a liquid bubble sound (100 to 400 Hz), a guttural expiration (about 800 Hz) produced during short-distance agonistic encounters, a roar (<800 Hz) for long-distance threats, a belch-cough made by males when patrolling (<1 kHz), and sneeze/snorts/coughs of variable frequencies that are <4 kHz (Miller and Job, 1992).

4.3.2.3 Northern elephant seal (*Mirounga angustirostris)* and Southern elephant seal *(M. leonina)*

The northern and southern elephant seals are not listed under the ESA nor are they categorized as depleted under the MMPA. The total population estimate for the northern elephant seal is over 150,000 (Jefferson et al., 2008). The population estimate for the California breeding stock of this species is 124,000 as of 2005 (Carretta et al., 2009). The population of southern elephant seals has been estimated at 650,000 seals (Jefferson et al., 2008). Two major populations of southern elephant seals are experiencing a decline while northern elephant seals are increasing in number.

Northern elephant seals occur throughout the northeast north-central Pacific Ocean (Jefferson et al., 2008). They occur during the breeding season from central Baja, Mexico to central California in about 15 colonies (LeBoeuf and Laws, 1994; Stewart and DeLong, 1994). Most of the colonies are located on offshore islands. Northern elephant seals make long, seasonal migrations between foraging and breeding areas, with some individuals making two return trips per year, returning to their southern breeding grounds to molt (Hindell and Perrin, 2009). Northern elephant seals are frequently observed along the coasts of Oregon, Washington, and British Columbia and may reach as far north as the Gulf of Alaska and the Aleutian Islands during foraging bouts (Le Boeuf, 1994). Southern elephant seals have a large range and occur on colonies around the Antarctic Convergence, between 40° and 62°S (King and Bryden, 1981; Laws, 1994). Breeding takes place near the sub-Antarctic zone and sometimes a pup is born on the Antarctic mainland. Southern elephant seals range throughout the Southern Ocean from the Antarctic Polar Front to the pack ice. During non-breeding seasons, both the southern and the northern elephant seals are widely dispersed (Hindell and Perrin, 2009).

Females achieve sexual maturity at ages thee to eight, with variation due to differences between species, populations and environmental changes. Breeding begins when males haul out to establish territories in August (southern elephant seal) or December (northern elephant seal). Territorial conflicts can be violent as the male that succeeds in defending a territory may reproductive access to up to 100 females. Pregnant females follow and give birth 2-5 days after arriving. Females remain with pups during lactation, which lasts 23-25 days in southern elephant seals and 26-28 days for northern elephant seals. Several days before weaning, the females mate with the dominant male (Hindell and Perrin, 2009).

Elephant seals spend as much as 90% of their time submerged and are remarkable divers, diving to depths >1,500 m (>4,921 ft) for 120 min to feed on deep-water fish and squids (Le Boeuf and Laws, 1994; Hindell and Perrin, 2009). In a study by Davis et al. (2001), an average elephant seal dive duration was recorded as 14.9 min to a maximum dive depth of 289 m (948 ft); average swimming speed was recorded as 1.1 m/sec (2.1 kts). Le Boeuf et al. (1989) reported that northern elephant seals dive to average depths of 500 to 700 m (1,640 to 2,297 ft) with most dives lasting 17 to 22.5 min with the longest dive duration as 62 min. Continuous deep dives are the normal state for these pelagic, deep divers. Dive depths and durations differ between adult male and females depending on the season and geographic location (Stewart, 2009).

Elephant seals may have poor in-air hearing sensitivity due to their aquatic and deep-diving lifestyle. Their ears may be better adapted for in-water hearing in terms of energy efficiency, which is reflected in the lower intensity thresholds under water, as well as receiving and transducing the mechanical stimulus which is reflected in the lower pressure thresholds under water (Kastak and Schusterman, 1999). Kastak and Schusterman (1999) found that hearing sensitivity in air is generally poor, but the best hearing frequencies were found to be between 3.2 and 15 kHz with the greatest sensitivity at 6.3 kHz and an upper frequency limit of 20 kHz (all at 43 dB re: 20 µPa). Underwater, the best hearing range was found to be between 3.2 and 45 kHz, with greatest sensitivity at 6.4 kHz and an upper frequency limit of 55 kHz (all at 58 dB RL) (Kastak and Schusterman, 1999). Kastak and Schusterman (1998) found that northern elephant seals can hear underwater sounds in the range of 75 Hz to 6.3 kHz. Kastak (1996) found hearing sensitivity increased for frequencies below 64 kHz, and the animals were still able to hear sounds below 100 Hz. One juvenile was measured as having a hearing threshold of 90 dB RL at 100 Hz (Fletcher et al., 1996). Since their hearing is better underwater, it is assumed that elephant seals are more sensitive to anthropogenic low frequency sound (Kastak and Schusterman, 1996). There are no direct hearing data available for southern elephant seals.

Elephant seals have developed high-amplitude, low-frequency vocal signals that are capable of propagating large distances. Elephant seals are highly vocal animals on their terrestrial rookeries and are not known to make any vocalizations underwater. Their in-air vocalizations are important for maintaining a social structure. Both sexes of all age classes are vocal. Two main sounds are produced by adults: calls of threat and calls to attract a mate. Yearlings often make a hissing sound (Bartholomew and Collias, 1962). The harmonics in pup calls may be important for individual recognition, extending to frequencies of 2 to 3 kHz (Kastak and Schusterman, 1999). The calls made by males are typically low-frequency, around 175 Hz (Fletcher et al., 1996).

Male northern elephant seals make three in-air sounds during aggression: snorting (200 to 600 Hz, clap threat (up to 2.5 kHz), and snoring (Frankel, 2009). In the air, mean frequencies for adult male northern elephant seal vocalizations range from 147 to 334 Hz (Le Boeuf and Peterson, 1969; Le Boeuf and Petrinovich, 1974). Burgess et al. (1998) recorded 300 Hz pulses from a juvenile female elephant seal between 220 to 420 m (722 to 1,378 ft) dive depths. Adult female northern elephant seals have been recorded with airborne call frequencies of 500 to 1,000 Hz (Bartholomew and Collias, 1962). Pups produce a higher frequency contact call up to 1.4 kHz (Frankel, 2009). There are no available data regarding seasonal or geographical variation in the sound production of either species.

4.3.2.4 Ribbon seal (*Phoca fasciata*)

Ribbon seals are classified as a data deficient species by the IUCN and are not considered to as depleted under the MMPA. Although not listed as threatened or endangered under the ESA, currently, the ribbon seal is considered a species of concern[10] throughout its range, principally due to the likely loss of the ribbon seal's sea ice habitat and its affect on recruitment and survival. Although no current abundance estimates are available for regional or global populations, Burns (1981) estimated the worldwide population of ribbon seals at 240,000 in the mid-1970s, with an estimate for the Bering Sea at 90,000-100,000, while Fedoseev (2000) reported an average population of 370,000 ribbon seals in the Sea of Okhotsk between 1968 and 1990. Mizuno et al. (2002) reported an average abundance of 2,697 seals for the southern Sea of Okhotstk off Hokaido, Japan for March through April 2000.

The distribution of ribbon seals is limited to the northern North Pacific Ocean and an area of the Arctic Ocean north of the Chukchi Sea, with predominant occurrence in the Bering Sea and Sea of Okhotsk

10 Species of concern are those species about which NMFS has some concerns regarding status and threats but for which insufficient information is available to indicate a need to list the species under the ESA.

(Jefferson et al., 2008; Fedoseev, 2009). Ribbon seals are associated with the southern edge of the pack ice from winter through early summer, where they pup and molt on the ice that is commonly found along the continental shelf where there is high water circulation (Fedoseev, 2009). During the summer months, ribbon seals have a pelagic phase that may encompass a broader distributional range than when the seals are dependent upon sea ice (Jefferson et al., 2008). Swim speeds and dive data are unknown for this species. Little is known of the foraging habits, although they do eat a wide variety of fishes (Lowry and Boveng, 2009).

Ribbon seals reach sexual maturity at ages between 3-5 years old. Breeding peaks in late April and early May. Births occur along the ice edge from March to April. Ribbon seals live to be about 25-30 years old (Lowry and Boveng, 2009).

There is no direct measurement of auditory threshold for the hearing sensitivity of the ribbon seal (Thewissen, 2002). Ribbon seals produce underwater sounds between 100 Hz and 7.1 kHz with an estimated SEL recorded at 160 dB (Watkins and Ray, 1977). These seals produce two types of underwater vocalizations, short, broadband puffing noises and downward-frequency sweeps that are long and intense, include harmonics, vary in duration, and do not waver; puffs last less than 1 second and are below 5 kHz while sweeps are diverse and range from 100 Hz to 7.1 kHz (Watkins and Ray, 1977). These authors speculated that these sounds are made during mating and for defense of their territories. There are no available data regarding seasonal or geographical variation in the sound production of this species.

4.3.2.5 Spotted seal (*Phoca largha*)

Spotted or largha seals are classified as a data deficient species by the IUCN. The Southern Distinct Population Segment of spotted seals, which consists of breeding concentrations in the Yellow Sea and Peter the Great Bay in China and Russia, is listed as threatened under the ESA. This species is not classified as depleted under the MMPA. The global population for this species is unknown. Jefferson et al. (2008) reported abundances of between 100,000 and 135,000 seals in the Bering Sea, 100,000 to 130,000 seals in the Sea of Okhotsk, and an estimated 4,500 seals in the Bohai Sea off China. The last reliable population estimate for the Bering Sea stock of spotted seals was estimated in 1992, with a maximum of 59,214 seals (Angliss and Allen, 2009). Trukhin (2005 as reported in Burns, 2009) reported an overall population estimate of 290,000 seals in the 1990s. Mizuno et al. (2002) reported an average abundance of 10,099 seals in the southern Sea of Okhotsk off Hokaido, Japan for March and April 2000. Additionally, Trukhin and Mizuno (2002) reported 1,000 spotted seals in Peter the Great Bay (southwestern Sea of Okhotsk area) and that this population had maintained this stable number of seals for at least 10 years.

Spotted seals occur in temperate to polar regions of the North Pacific Ocean from the Sea of Okhotsk, the Sea of Japan, and the Yellow Sea to the Bering and Chukchi Seas into the Arctic Sea to the Mackenzie River Delta (Jefferson et al., 2008). Spotted seals spend their time either in open-ocean waters or in pack-ice habitats throughout the year, including the ice over continental shelves during the winter and spring (Burns, 2009). This species hauls out on sea ice but also comes ashore on land during the ice-free seasons of the year. The range of spotted seals contracts and expands in association with the ice cover; their distribution is most concentrated during the period of maximum ice cover (Burns, 2009).

When the ice cover recedes in the Bering Sea, some spotted seals migrate northward into the Chukchi and Beaufort Seas. These animals spend the summer and fall near Point Barrow in Alaska and the northern shores of Chukotka, Russia. With increasing ice cover, the spotted seals migrate southward through the Chukchi and Bering Sea region to maintain association with drifting ice. Peak haul-out time is during molting and pupping from February to May (Burns, 2009). Spotted seals are a generalist predator, feeding on fish, squid and invertebrates. Prey composition varies seasonally and regionally, reflecting the local distribution of prey species. Swim speeds and dive times of this species are not known. Dives as deep as 300 to 400 m (984 to 1,312 ft) have been reported for adult spotted seals with pups diving to 80 m (263 ft) (Bigg, 1981).

Spotted seals are aquatic maters. They form pairs before estrus begins are seasonally monogamous with the males maintaining territories in the ice. The timing of reproduction varies seasonally and regionally, and appears to be based on the time of best ice conditions. Pups are born on the ice and for the first 2-3 weeks of their lives remain mostly on the ice and nursing lasts 4 weeks (Burns, 2009).

There is no direct measurement of auditory threshold for the hearing sensitivity of the spotted seal (Thewissen, 2002). Underwater vocalization of captive seals increased 1 to 2 weeks before mating and was higher in males than females. Sounds produced were growls, drums, snorts, chirps, and barks ranging in frequency from 500 Hz to 3.5 kHz (Richardson et al., 1995).

4.3.2.6 Harbor seal (*Phoca vitulina*)

Harbor seals are also known as common seals. This species is classified as least concern (lower risk) by the IUCN, is not listed as threatened or endangered under the ESA, and is not categorized as depleted under the MMPA. The global population of harbor seals is estimated to be between 300,000 and 500,000 seals (Jefferson et al., 2008). Five subspecies of the harbor seal have been classified throughout the Northern Hemisphere. In the western North Atlantic there are an estimated 99,340 seals (Waring et al., 2009). In Alaska including the Gulf of Alaska and the Bering Sea, the statewide population of harbor seals is estimated to be 180,017 individuals (Angliss and Allen, 2009). The California stock estimate of harbor seals is estimated to be 34,233 seals, while in Oregon and Washington, 24,732 seals are estimated (Carretta et al., 2009). In inland Washington, there are an estimated 14,612 harbor seals (Carretta et al., 2009).

Harbor seals are one of the most widely distributed pinnipeds in the world. This species is widely distributed in Polar and temperate waters along the margins of the eastern and western North Atlantic Ocean, and the North Pacific Ocean (Jefferson et al., 2008). They also can be found in the southern Arctic Ocean (Jefferson et al., 2008). This species is most commonly found in coastal waters of the continental shelf waters, and can be found in rivers, bays, and estuaries (Jefferson et al., 2008). They primarily inhabit areas that are ice-free. The greatest numbers of breeding animals occur in the northern temperate zone. However, breeding colonies occur both north and south of the zone, depending on environmental, oceanic, and climate conditions.

Harbor seals are generally considered to be sedentary, but their known seasonal and annual movements are varied. They haul out mainly on land, but they do use icebergs in Alaska and Greenland. When they haul out on land, they prefer natural substrates of mud flats, gravel bars and beaches, and rocks. Breeding grounds are generally associated with isolated places such as pack ice, offshore rocks, and vacant beaches (Riedman, 1990). This species feeds on a wide variety of prey items, frequently reflecting local abundance of fish, squid and invertebrate species (Burns, 2009).

Harbor seals mate in the water. Males maintain territories, usually near haulout areas or female movement corridors, with dive and vocal displays. Males appear to show site fidelity, returning to the same area over many years. The mating system is polygynous. Females reach sexual maturity at ages 3-4 and males at ages 4-5. Mating and weaning take place at the same time within each population, although this time varies from late winter to summer among the different populations. The total gestation time, from mating to birth is approximately 10.5 months, including delayed implantation and most females give birth every year (Burns, 2009).

Maximum swim speeds have been recorded over 13 km/hr (7 kts) (Bigg, 1981). The deepest diving harbor seal was located in Monterey Bay, California, and dove to a depth of 481 m (1,578 ft), and the longest dive lasted 35.25 min (Eguchi and Harvey, 2005). In general, seals dive for less than 10 min, and above 150 m (492 ft) (Jefferson et al., 2008).

Hanggi and Schusterman (1994) and Richardson et al. (1995) reported harbor seal sounds. Social sounds ranged from 0.5 to 3.5 kHz, Clicks range from 8 to more than 150 kHz with dominant frequencies between 12 and 40 kHz. Roars range from 0.4 to 4 kHz with dominant frequencies between 0.4 and 0.8 kHz. Bubbly growls range from less than 0.1 to 0.4 kHz with dominant frequencies at less than 0.1 to 0.25 kHz. Grunts and groans range from 0.4 to 4 kHz. Creaks range from 0.7 to 7 kHz with dominant frequencies between 0.7 and 2 kHz. This species creates a variety of sounds including clicks, groans, grunts, and creaks.

Van Parijs et al. (2000) studied the variability in vocal and dive behavior of male harbor seals at both the individual and the geographic levels. Harbor seals are an aquatic-mating species. The females are forced to forage to sustain a late lactation. For this reason, harbor seals are widely distributed throughout the mating season. Male harbor seals produce underwater vocalizations and alter their dive behavior during mating season. In Scotland, male harbor seals are found to alter their dive behavior in the beginning of July for the mating season. They change from long foraging dives to short dives. Changes in dive behavior during the mating season have also been reported in Norway and Canada. Individual variation in vocalization of male harbor seals has also been recorded in California breeding populations. Male vocalizations also varied individually and geographically in Scotland. This study showed the variability in male vocalizations individually and geographically, as well as the change in dive behavior (Van Parijs et al., 2000).

Van Parijs and Kovacs (2002) studied the eastern Canadian harbor seal in-air and underwater vocalizations. It was determined that harbor seals produce a range of in-air vocalizations and one type of underwater vocalization. The number of vocalizations increased proportionally with the number of individuals present at the haul out sites. In-air vocalizations were predominantly emitted by adult males during agnostic interactions, which suggest that in-air vocalizations are used during male competition. In-air vocalizations were also produced by adult females and sub-adult males which suggest that some types of in-air vocalizations may serve for general communication purposes. The harbor seals in the study also produced underwater roar vocalizations during the mating season. These vocalizations are similar to that of other harbor seals in other geographic locations (Van Parijs and Kovacs, 2002).

The harbor seal can hear sounds in the range of 75 Hz to a maximum of 180 kHz (Mohl, 1968b; Terhune, 1991; Kastak and Schusterman, 1998). Richardson et al. (1995) reported that phocid seals have a mostly flat audiogram from 1 kHz up to approximately 50 kHz with hearing thresholds between 60 and 85 dB RL. In a study by Wolski et al. (2003), harbor seals' hearing was measured using the method of constant stimuli. It was found that harbor seals have good sensitivity between 6 and 12 kHz, and the best sensitivity at 8 kHz at 8.1 dB re 20 μPa^2sec (Wolski et al., 2003).

4.3.2.7 Gray seal (*Halichoerus grypus*)

Gray seals are classified as a least concern (lower risk) species by the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. Gray seals have a global population estimate of 380,000 seals (Jefferson et al., 2008). In the western North Atlantic there is an estimated population of 125,541 to 169,064 seals (Waring et al., 2009) In the Baltic Sea there is an estimated 17,600 gray seals (Jefferson et al., 2008).

Gray seals occur in temperate and sub-polar regions mostly in the north Atlantic Ocean Baltic Sea and the eastern and North Atlantic (Jefferson et al., 2008). Gray seals feed on a wide variety of fish and cephalopods, but specialize on sand lance, which can make up to 70% of their diet (Hall and Thompson, 2009) .Gray seals breed on remote islands that are typically uninhabited or on fast ice. The biggest island breeding colony is on Sable Island (Hall and Thompson, 2009). Gray seals give birth on drifting ice and offshore islands throughout their range between September and March. Females nurse for about 18 days. Toward the end of lactation the females come into estrus. Males compete for access to females but do not hold territories. Most females give birth every year. This species is not known to undergo seasonal movements (Hall and Thompson. 2009).

Swim speeds average 4.5 km/hr (2.4 kts). Gray seals dives are short, between 4 and 10 min, with a maximum dive duration recorded at 30 min (Hall and Thompson, 2009). A maximum dive depth of over 300 m (984 ft) has been recorded for this species, but most dives are relatively shallow, from 60 to 100 m (197 to 328 ft) to the seabed (Hall and Thompson, 2009).

Gray seals' underwater hearing range has been measured from 2 kHz to 90 kHz, with best hearing between 20 kHz and 50 to 60 kHz (Ridgway and Joyce, 1975). Gray seals produce in-air sounds at 100 Hz to 16 kHz, with predominant frequencies between 100 Hz and 4 kHz for seven characterized call types, and up to 10 kHz for "knock" calls (Asselin et al., 1993). Oliver (1978) has reported sound frequencies as high as 30 and 40 kHz for these seals. There is no available data regarding seasonal or geographical variation in the sound production of gray seals.

4.3.2.8 Hooded seal (*Cystophora cristata*)

Hooded seals are classified as a vulnerable species by the IUCN but are not listed under the ESA nor are categorized as depleted under the MMPA. The global population of hooded seals is estimated at 660,000 seals (Kovacs, 2009). Three stocks are recognized to set harvest quotas: Canadian, Davis Strait, and the West Ice (west of Jan Mayen Island) stocks (Kovacs, 2009). The abundance of the West Ice stock has been stable at around 70,000 hooded seals for the last 20 years (Kovacs, 2009).

Hooded seals are found in the high latitudes of the North Atlantic Ocean, and in the Arctic Ocean (Jefferson et al., 2008). Hooded seals are solitary animals except when breeding or molting and are found in the deeper waters of the North Atlantic, primarily off the east coast of Canada, Gulf of St. Lawrence, Newfoundland, Greenland, Iceland, Norwegian waters, and the Barents Sea. They feed on a wide variety of pelagic fish species (Kovacs, 2009). Their winter distribution is poorly understood, but some seals inhabit the waters off Labrador and northeastern Newfoundland, on the Grand Bank, and off southern Greenland (Jefferson et al., 2008). Records of migrant hooded seals are not unusual, with juveniles having been observed as far south as Portugal, the Caribbean Sea, and California (Mignucci-Giannnoni and Odell, 2001).

Breeding takes place in this range from late March to the beginning of April for a two to three week period. They are associated with the outer edge of pack ice and drifting ice throughout much of the year (Reeves et al., 2002). They congregate on ice floes for both mating and pupping. Females in the Gulf of St. Lawrence haul out on ice floes in large congregations. In the summer, hooded seals are found along the Greenland coast and as far north as Cape York. Hooded seals are a migratory species and are often seen far from their haul-outs and foraging sites. They tend to follow the annual movement of the drifting pack ice (Kovacs, 2009).

Females achieve sexual maturity at age of three years. Males probably have to age longer before they can successfully compete for females. Hooded seals live to be about 25-35 years old (Kovacs, 2009).

Swim speeds are not known. On average, dive times have been recorded at 15 min or longer. Dive depths range between 100 to 600 m (300 to 2,000 ft). A maximum dive record shows a depth of over 1,000 m (3,280 ft) lasting almost an hour (Kovacs, 2009).

There is no direct measurement of auditory threshold for the hearing sensitivity of the hooded seal (Thewissen, 2002). Hooded seals produce a variety of distinct sounds ranging between 500 Hz and 6 kHz (Frankel, 2009). There are at least three types of LF, pulsed sounds, described as grunt, snort, and buzz that are made by the male underwater. The grunt noise has the highest intensity in the 0.2 and 0.4 kHz range (Terhune and Ronald, 1973). The snort has a broad band of energy ranging between 0.1 and 1 kHz with harmonics occasionally reaching 3 kHz. The buzz has most of its energy at 1.2 kHz with side bands and harmonics reaching 6 kHz (Terhune and Ronald, 1973). All three calls exhibited some pulsing. Female calls in air have major intensities at frequencies of less than 0.5 kHz with a low harmonic and an exhalation of 3 kHz at the end of the call. The sounds produced by hooded seals have a variety of functions ranging from female-pup interactions to fighting behavior and visual displays among males

(Terhune and Ronald, 1973; Frankel, 2009). The source levels of these sounds have not been estimated, and there are no available data regarding seasonal or geographical variation in the sound production of hooded seals.

4.3.2.9 Harp seal (*Pagophilus groenlandicus*)

The harp seal is considered a species of least concern by the IUCN. This species is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. Population sizes for the three stocks of harp seals in the North Atlantic Ocean were recently estimated as 5.5 million seals for the northwest Atlantic stock, 741,670 animals in the West Ice stock (Greenland Sea near Jan Mayen Island), and 2,425,480 seals in the White Sea (Lavigne, 2009; Waring et al., 2009).

Harp seals only occur in the North Atlantic and Arctic Oceans and adjacent seas from northern Russia to Newfoundland and the Gulf of St. Lawrence, Canada in three defined stocks: the “Front” or northwest Atlantic (Newfoundland, Labrador, and the Gulf of St. Lawrence), the “West Ice” or Greenland Sea near Jan Mayen Island, and the “East Ice” in the Barents and White Seas (Waring et. al., 2009). Since 1994, however, increasing and substantial numbers of harp seals, often juveniles, have been recorded in the western North Atlantic from the Gulf of Maine southward to New Jersey (McAlpine and Walker, 1999; McAlpine et al., 1999; Harris et al., 2002). In the nearly 150 years prior to 1994, only 16 harp seals were reported in the northern Gulf of Maine, while recently more than that number are now reported annually in the Gulf of Maine and southern New England (McAlpine et al., 1999; Waring et al., 2009). Reports of increasing numbers of reported harp seals along the coast of western continental Europe (Denmark to northern Spain) have also reported within the same time period (Van Bree, 1997). The southern limit of the harp seal’s range in the western North Atlantic is now considered to extend into the northeastern U.S. waters during winter and spring (Waring et al., 2009).

Previously, harp seals were thought to be shallow divers, but dives to maximum water depths of 568 m (Folkow et al., 2004) and dive durations up to 16 min (Schreer and Kovacs, 1997) now demonstrate that harp seals are moderately deep divers. Folkow et al. (2004) found that more than 12% of all dives recorded during their study were to depths more than 300 m. Harp seal’s mean dive durations range from 3.8 to 8.1 min (Lydersen and Kovacs, 1993; Folkow et al., 2004). Harp seals feed on a wide variety of prey species, with at least 67 fish species and 70 invertebrates having been reported from their stomach contents (Lavigne, 2009).

Females achieve sexual maturity at a mean age of 5.3 years, males probably require a slightly longer time. Females assemble at the southern end of their range from late February to early March to give birth. Pups are nursed for 12 days, at which point the females abandon them on the ice and return to the water to mate. The pup remains on the ice for up to six weeks until they enter the water to begin foraging. Harp seals can live to more than thirty years (Lavigne, 2009).

The ear of the harp seal is adapted to hear better underwater than in air, as demonstrated by the decreased hearing sensitivity measured in air (Terhune and Ronald, 1972). In-water, harp seals hearing was measured by freefield audiogram from 760 Hz to 100 kHz, with greatest sensitivity at 2 and 23 kHz and thresholds between 60 and 85 dB re 1 µPa (Terhune and Ronald, 1972; Richardson et al., 1995), while the in-air audiogram, measured from 1 to 32 kHz, has the lowest threshold at 4 kHz while the frequency range from 16 to 32 kHz remains constant (Terhune and Ronald, 1971; Ronald and Healey, 1981). Above 64 kHz, the in-water hearing threshold increases by 40 dB per octave (Ronald and Healey, 1981).

Harp seals produce as many as 26 different underwater vocalizations that are usually short in duration and have been described as whistles, grunts, trills, chirps, clicks, knocks, and squeaks (Ronald and Healey, 1981; Serrano, 2001). These seals are especially vocal during breeding, producing as many as 135 calls/min (Serrano and Terhune, 2002). Frequencies of the varied in-water vocalizations range from about 400 to 849 Hz while in-air vocalizations are lower, at about 206 Hz (Serrano, 2001). Harp seals most likely use frequency and temporal separation of their vocalizations together with a wide vocal repertoire (as many as 26 call types) to avoid masking one another (Serrano and Terhune, 2002).

5 TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

Requirement 5: *Type of incidental take authorization that is being requested (i.e., takes by harassment only; takes by harassment, injury, and/or death) and the method of incidental taking.*

Pursuant to Section 101 (a)(5)(A) of the Marine Mammal Protection Act of 1972, as amended (MMPA;16 USC 1371), the Department of the Navy (DoN) is applying for rulemaking and Letters of Authorization (LOAs) for the employment of Surveillance Towed Array Sensor System (SURTASS) Low Frequency Active (LFA) sonar during training, testing, and routine military operations. The MMPA directs the Secretary of Commerce (Secretary) to allow, upon request, the incidental, but not intentional taking of marine mammals by U.S. citizens who engage in a specified activity (other than commercial fishing) during periods of not more than five consecutive years. The issuance occurs when the Secretary, after notice has been published in the *Federal Register* and opportunity for comment has been provided, finds that such takes will have a negligible impact on the species and stocks of marine mammals and will not have an unmitigable adverse impact on their availability for subsistence uses. Marine mammals will be harassed due to the underwater noise generated incidental to the employment of SURTASS LFA sonar systems during at-sea operations. As a result, DoN (hereafter, the Navy) is requesting LOAs and rulemaking under the MMPA for taking of marine mammals by Level A and Level B (non-lethal) harassment incidental to the employment of up to four SURTASS LFA sonar systems within restricted areas of the world's oceans for the five year period from August 2012 through August 2017.

This application for rulemaking and LOAs is the third such application the DoN has submitted to the National Marine Fisheries Service (NMFS) for employment of SURTASS LFA sonar. In 2002, NMFS issued regulations and the initial LOA (NOAA, 2002) under the MMPA Final Rule (50 CFR §216 Subpart Q) (NOAA, 2002a) for the operation of SURTASS LFA sonar on the research vessel (RV) *Cory Chouest*. The Navy requested and was issued annual LOA renewals in accordance with 50 CFR §216.189 for the remaining four years of the 2002 Final Rule for the research vessel (RV) *Cory Chouest* and USNS IMPECCABLE. In 2006, the Navy submitted its application for the second five-year Rule under MMPA (DoN, 2006) for the taking of marine mammals by Level A and Level B harassment incidental to the deployment of up to four SURTASS LFA sonar systems for military readiness activities from 16 August 2007 to 15 August 2012. NMFS published the second MMPA Final Rule in August 2007 (NOAA, 2007) for the employment of SURTASS LFA sonar, and subsequently in 2007 issued annual LOAs for sonar use on the RV *Cory Chouest,* USNS ABLE, USNS VICTORIOUS, and USNS IMPECCABLE.

This application document has been prepared in accordance with applicable regulations and the MMPA, as amended by the National Defense Authorization Act (NDAA) for Fiscal Year 2004. The NDAA modified the MMPA by removing the ''small numbers'' and ''specified geographical region'' limitations and amended the definition of ''harassment'' as it applies to a ''military readiness activity." The basis of this rulemaking and LOA request are (1) the analysis of spatial and temporal distributions of protected marine mammals in potential operating areas for SURTASS LFA sonar, (2) a review of activities that have the potential to affect marine mammals, and (3) a technical risk assessment to determine the likelihood of effects from use of SURTASS LFA sonar during Navy training, testing, and routine military operations in the world's oceans, with specific geographic areas exempted from operations.

6 INCIDENTAL TAKES

<u>Requirement 6</u>: *Age, sex, and reproductive condition (if possible), the number of marine mammals (by species) that may be taken by each type of taking identified in paragraph (a)(5) of this section, and the number of times such takings by each type of taking are likely to occur.*

For SURTASS LFA sonar operation, potential impacts to marine mammals should be assessed in the context of the basic operational characteristics of the system:

- A maximum of four operating sonar systems aboard four SURTASS LFA vessels will be deployed in the Pacific-Indian Ocean area and in the Atlantic Ocean-Mediterranean Sea area.
- The USNS IMPECCABLE (T-AGOS 23) is equipped with a SURTASS LFA sonar system. Three additional VICTORIOUS Class (T-AGOS 19) platforms have been, or will be, equipped with compact LFA systems by the end of FY2012. These vessels are U.S. Coast Guard-certified for operations. In addition, these vessels will operate in accordance with all applicable federal and U.S. Navy rules and regulations related to environmental compliance. SURTASS LFA sonar vessel movements are not unusual or extraordinary and are part of routine operations of seagoing vessels. Therefore, there should be no unregulated environmental impacts from the operation of the SURTASS LFA sonar vessels.
- At-sea missions would be temporary in nature. Of an estimated maximum 294 underway days per year per vessel, the SURTASS LFA sonar would be operated in the active mode a maximum of 240 days. During these 240 days, active transmissions would occur for a maximum of 432 cumulative hours per year per vessel.
- Average duty cycle (ratio of sound “on” time to total time) of the SURTASS LFA sonar active transmission mode is less than 20%. The typical duty cycle, based on historical LFA operational parameters since 2003, is nominally 7.5 to 10%. That is, 7.5 to 20% of the time, the LFA transmitters could be on while 80 to 92.5% of the time the LFA transmitters would be off, thus adding no sound into the water. On an annual basis, each SURTASS LFA vessel is limited to transmitting no more than 4.9% of the time (or 432 hrs out of 8,760 hrs).

The types of potential effects on marine mammals from SURTASS LFA sonar operations can be broken down into several categories:

- **Non-auditory injury**: This includes the potential for resonance of the lungs/organs, tissue damage, and mortality. For the purposes of the SURTASS LFA sonar analyses presented here, all marine mammals exposed to underwater sound ≥180 dB SPL received level (RL) are evaluated as if they are injured (Level A “harassment” under the MMPA). Even though actual injury would not occur unless animals were exposed to sound at a level greater than this value (Southall et al., 2007), the analysis in the document will continue to define LFA’s injury level as ≥180 dB SPL RL. This should be viewed as a conservative value, used to maintain consistency in the analytical methodologies utilized in SURTASS LFA impact statements (DoN, 2001, 2007, 2011), in incidental take applications under the Marine Mammal Protection Act (MMPA), and in consultations under the ESA.
- **Permanent threshold shift (PTS)**: A severe situation occurs when sound intensity is very high or of such long duration that the result is a permanent hearing loss on the part of the listener, which is referred to as permanent threshold shift (PTS). This constitutes Level A “harassment” under the MMPA. The intensity and duration of an underwater sound that will cause PTS varies across marine mammal species and even among individual animals. PTS is a consequence of the death of the sensory hair cells of the auditory epithelia of the ear with a resultant loss of hearing ability in the general vicinity of the frequencies of stimulation (Salvi et al., 1986; Myrberg, 1990; Richardson et al.,

1995). PTS results in a permanent elevation in hearing threshold—an unrecoverable reduction in hearing sensitivity (Southall et al., 2007).

- **Temporary threshold shift (TTS)**: Underwater sounds of sufficient loudness can cause an transient condition known as temporary threshold shift (TTS), in which an animal's hearing is impaired for a period of time. After termination of the sound, normal hearing ability returns over a period that may range anywhere from minutes to days, depending on many factors, including the intensity and duration of exposure to the intense sound. Hair cells may be temporarily affected by exposure to the sound, but they are not permanently damaged or killed. Thus, TTS is not considered an injury (Richardson et al., 1995; Southall et al., 2007), although during a period of TTS, animals may be at some disadvantage in terms of detecting predators or prey.
- **Behavioral change**: Various vertebrate species are affected by the presence of intense sounds in their environment (Salvi et al., 1986; Richardson et al., 1995). Behavioral responses to these sounds vary from subtle changes in surfacing and breathing patterns to cessation of vocalization or even active avoidance or escape from regions of high sound levels (Wartzok, et al., 2004). For military readiness activities, such as the use of SURTASS LFA sonar, Level B "harassment" under the MMPA is defined as any act that disturbs or is likely to disturb a marine mammal by causing disruption of natural behavioral patterns to a point where the patterns are abandoned or significantly altered. Behaviors include migration, surfacing, nursing, breeding, feeding, and sheltering. In a discussion on biologically significant behaviors and possible effects, the National Research Council (NRC) noted that an action or activity becomes biologically significant to an individual animal when it affects the ability of the animal to grow, survive, and reproduce; these are the effects on individuals that can have population-level consequences and affect the viability of the species (NRC, 2005).
- **Masking**: The presence of intense sounds in the environment can potentially interfere with an animal's ability to hear relevant sounds. This effect, known as "auditory masking", could interfere with the animal's ability to detect biologically-relevant sounds, such as those produced by predators or prey. During auditory masking, an animal may, thus, not be able to locate food or escape predacious attack.

6.1 NON-AUDITORY INJURY

Nowacek et al. (2007) and Southall et al. (2007) reviewed potential areas for non-auditory injury to marine mammals from active sonar transmissions. These include direct acoustic impact on tissue, indirect acoustic impact on tissue surrounding a structure, and acoustically mediated bubble growth within tissues from supersaturated dissolved nitrogen gas.

6.1.1 DIRECT ACOUSTIC IMPACTS

Physical effects, such as direct acoustic trauma or acoustically enhanced bubble growth, require relatively intense received energy that would only occur at short distances from high-powered sonar sources (Nowacek et al., 2007; Zimmer and Tyack, 2007). The best available scientific information shows that, while resonance can occur in marine animals, this resonance does not necessarily cause injury, and any such injury is not expected to occur below a RL of 180 dB. Damage to the lungs and large sinus cavities of cetaceans from air space resonance is not regarded as a likely significant non-auditory injury because resonance frequencies of marine mammal lungs are below that of the LFA signal (Finneran, 2003). Further, biological tissues are heavily damped and tissue displacement at resonance is predicted to be exceedingly small. In addition, lung tissue damage is generally uncommon in acoustic-related strandings (Southall et al., 2007).

6.1.1.1 Gas Bubble Formation

Presently, there are discussions among researchers regarding the potential for marine mammals to suffer from a form of decompression sickness caused by in vivo nitrogen gas-bubble growth. Jepson et al. (2003, 2005) and Fernandez et al. (2005) reported results of necropsies of stranded beaked whales, some of which coincided with naval sonar exercises, which they interpreted as consistent with a decompression-like syndrome (Nowacek et al., 2007).

Scientists have documented bone lesions (osteonecrosis), which may be a chronic result of nitrogen bubbles, in the rib and chevron bone articulations, nasal bones, and deltoid crests of sperm whale specimens from the Atlantic and Pacific Oceans dating from the late 1800s to 2003, (Moore and Early, 2004). This suggests that nonlethal pathologies related to gas bubbles may occur during the normal life span of, at least, the deep-diving sperm whale. Houser (2007) assessed the potential for nitrogen bubble formation in a trained dolphin. Based on repetitive dives to depths of 10, 30, 50, 70, and 100 m (32.8, 98.4, 164, 230, and 328 ft), ultrasound inspections were completed on the portal and innominate veins (i.e., the left and right brachiocephalic veins). Blood samples were also taken over a 20-minute (min) period at the end of each of the 50, 70, and 100 m (164, 230, and 328 ft) dives for the assessment of nitrogen partial pressure. There were no vascular bubbles found in any post-dive ultrasound. Nitrogen partial pressures from blood samples were not significantly elevated from those of the dolphin at rest (20 min post dive). Results suggest that repetitive, prolonged dives up to 100 m (328 ft) accumulate insufficient nitrogen to generate asymptomatic intravascular bubbles in bottlenose dolphins.

Zimmer and Tyack (2007) modeled nitrogen tension and bubble growth in beaked whales during normal diving behavior and for several hypothetical dive profiles to assess the risk of nitrogen bubble formation. These authors concluded that macroscopic bubbles are unlikely to pose a risk of decompression-like syndrome from a simple interruption of a normal deep foraging dive, even when accompanied by an unrealistic ascent rate. Zimmer and Tyack (2007) concluded, contrary to the findings of Jepson et al. (2003), that the interruption and rapid ascent from a regular deep foraging dive is unlikely to pose a risk of decompression-like syndromes; they suggested that gas bubble lesions in stranded beaked whales reported by Jepson et al. (2003, 2005) and Fernandez et al. (2005) might be caused by repetitive dives of short to medium surfacing duration without exceeding the depth of alveolar collapse. Also, Zimmer and Tyack (2007) found that the longer the dive time compared to surfacing time, the greater the risk; the authors suggested the hypothesis that beaked whales have an avoidance response to killer whales and great white sharks, which are their primary near-surface predators, resulting in their swimming at depths of approximately 25 m (82 ft) without exceeding alveolar collapse. This hypothesis requires more behavioral and physiological research.

Baird et al. (2008) investigated the variation in diving behavior from time-depth recorders on six Blainville’s and two Cuvier’s beaked whales. Both species demonstrated ascent rates from dives deeper than 800 m (2,625 ft) that were significantly slower than decent rates, both during the day and at night, suggesting some physiological purpose for the slower ascents. The whales also spent more time in dives to mid-water depths (100 to 600 m [328 to 1,969 ft]) during the day. At night, the whales spent more time in shallow (<100 m) dives. This diel variation[11] in behavior suggests that beaked whales may spend less time in surface waters during the day to avoid visually oriented predators, including sharks and killer whales.

Fahlman et al. (2009) modeled the effects of lung compression and collapse (pulmonary shunt) on the uptake and removal of oxygen, carbon dioxide, and nitrogen in blood and tissue, and on end-dive nitrogen concentrations for breath-holding marine mammals (e.g., elephant seals, Weddell seals, and beaked whales). Fahlman et al. suggested that repeated dives might result in tissue and blood levels of nitrogen sufficient to cause symptomatic bubble formation.

Based on the current knowledge of gas exchange and physiology of marine mammals, Hooker et al. (2009) developed a mathematical model to predict blood and tissue levels of nitrogen gas for three species of beaked whales: northern bottlenose, Cuvier’s, and Blainville’s beaked whales. Hooker et al. suggested that deep-diving marine mammals live with and manage high levels of nitrogen gas in their

11 Diel means "in the course of the day". Thus, a "diel variation" is a variation that occurs regularly every day or most days.

tissues and blood. Due to differences in dive behavior, predicted nitrogen levels were higher in Cuvier's beaked whales than in northern bottlenose whales and Blainville's beaked whales. Hooker et al. (2009) state that while the prevalence of Cuvier's beaked whale strandings after naval sonar exercises could be explained by a higher abundance of the species in the area, their results suggest that species differences in behavior and/or physiology may also play a role.

Moore et al. (2009) performed gross histologic and radiographic observations related to the presence of gas bubbles in the tissues and blood of seals and dolphins drowned in gillnets, set at a depth of approximately 80 m (263 ft). The majority (15 of 23) of the seals and dolphins had extensive bubble formation in multiple tissues and blood. In addition, computer tomography (CT), which was performed on four randomly-selected marine mammals, identified gas bubbles in various tissues. Due to the good condition of the carcasses, absence of bacteria and autolytic (self-digestion) changes, the study concluded that peri- or post-mortem phase change of supersaturated blood and tissues was the most likely cause of the bubbles. Overall, Moore et al. (2009) found a high prevalence of vascular and interstitial bubbles in seals and dolphins drowned in gillnets set at a depth of approximately 80 m (263 ft). In contrast, a very low prevalence of bubble lesions was found for beach-stranded marine mammals in this study (one of 41) and in a study by Jepson et al. (2005) (10 of 2,376). The results of the Moore et al. (2009) analyses support the modeling of simulated dive profiles by Zimmer and Tyack (2007), which suggest an increase in risk of bubble formation caused by repetitive dives with short to medium surface durations, without exceeding the depth of alveolar collapse, which is estimated to be about 80 m (263 ft) for dolphins.

Despite the increase in research and literature, there remains scientific disagreement and/or lack of scientific data regarding the evidence for gas bubble formation as a causal mechanism between certain types of acoustic exposures and stranding events. These issues include: 1) received acoustic exposure conditions; 2) pathological interpretation; 3) acoustic exposure conditions required to directly induce physiological trauma; 4) behavioral reactions caused by sound exposure such as atypical dive patterns; and 5) the extent of postmortem artifacts (Southall et al., 2007).

The hypotheses for gas bubble formation related to beaked whale strandings is that beaked whales potentially have strong avoidance responses to MFA sonars because they sound similar to their main predator, the killer whale (Cox et al., 2006; Southall et al., 2007; Zimmer and Tyack, 2007; Baird et al., 2008; Hooker et al., 2009). Because SURTASS LFA sonar transmissions are lower in frequency (<500 Hz) and dissimilar in characteristics from those of marine mammal predators, the above scientific studies do not provide additional evidence that SURTASS LFA sonar has caused behavioral reactions, specifically avoidance responses, in beaked whales. Thus, SURTASS LFA sonar transmissions are not expected to cause gas bubble formation or beaked whale strandings.

6.1.2 INJURY CRITERIA

Southall et al. (2007) proposed injury criteria for individual LF/MF/HF marine mammal groups exposed to non-pulsed sound type, which included discrete acoustic exposures from SURTASS LFA sonar. The proposed injury criteria, which are based on onset of PTS, for LF/MF/HF cetaceans are an SEL of 215 dB RL and for pinnipeds in water an SEL of 203 dB RL. These values are then adjusted for the longer LFA signal (nominally 60 seconds), using 10 Log (T/Ti) where T is 60 sec and Ti is 1 sec. An 18-dB adjustment is made, resulting in an injury criterion for SURTASS LFA sonar of an SEL of 197 dB RL for cetaceans. For pinnipeds in water, this adjusted value would be an SEL of 185 dB RL.

6.2 AUDITORY EFFECTS OF SOUND ON MARINE MAMMALS

All studied marine mammals produce sound. They use sound to communicate with conspecifics, to navigate and sense their environment, to locate and capture prey, and to detect and avoid predators (Hofman, 2003; Southall et al., 2007). Marine mammals exposed to natural or man-made sound may experience physical and psychological effects, ranging in magnitude from none to severe (Southall et al., 2007). There are at least four areas of primary concern for marine mammals exposed to elevated noise levels, including: 1) PTS; 2) TTS; 3) behavioral disturbance (Nowacek et al., 2007); and 4) acoustic masking (Clark et al., 2009).

The hearing of marine mammals varies among species and individuals (Richardson et al., 1995). An auditory threshold, estimated by either behavioral or electrophysiological responses, are the levels of the quietest audible sound in a specified percent of trials (i.e., often 50% detection probability) (Southall et al, 2007). Generally, audiograms have been developed for smaller, captive odontocetes and pinnipeds. The absolute threshold is the level of sound that is barely audible when significant ambient noise is absent, which also varies based on the frequency content of the sound. Background noise may mask the sounds that a marine mammal could normally detect; masking can come from both natural and man-made noises (Richardson et al., 1995).

Southall et al. (2007) created five functional hearing groups of marine mammals by combining behavioral and electrophysiological audiograms with comparative anatomy, modeling, and response measured in ear tissues. These are:

- Low-frequency Cetaceans—this group consists of 13 species and subspecies of mysticetes with a collective functional hearing of 7 Hz to 22 kHz.
- Mid-frequency Cetaceans—includes 32 species and subspecies of dolphins, six species of larger toothed whales, and 19 species of beaked and bottlenose whales with functional hearing of approximately 150 Hz to 160 kHz.
- High-frequency Cetaceans—incorporates eight species and subspecies of true porpoises, six species and subspecies of river dolphins, plus the franciscana, *Kogia*, and four species of Cephalorhynchids (genus in the dolphin family Delphinidae) with functional hearing estimated from 200 Hz to 180 kHz.
- Pinnipeds in Water—consists of 16 species and subspecies of sea lions and fur seals, 23 species and subspecies of true seals, and two species of walrus, with functional underwater hearing from 75 Hz to 75 kHz.
- Pinnipeds in Air—includes 16 species and subspecies of sea lions and fur seals, 23 species and subspecies of true seals, and two subspecies of walrus, with functional in air hearing from 75 Hz to 30 kHz (Southall et al., 2007).

Measured sensitivity and frequency ranges of marine mammals are shown by audiograms, which are obtained by either: 1) behavioral testing on captive, trained animals; or 2) by electrophysiological or auditory evoked potential (AEP) methods (Schlundt et al., 2007). Currently, there are no audiograms for low-frequency cetaceans available. However, predictions of their hearing have been made on the basis of cochlear anatomy (Ketten, 1997) and environmental acoustics (Clark and Ellison, 2004). Audiograms, both behavioral and AEP, for mid-frequency cetaceans include those for bottlenose dolphin, common dolphin, killer whale, beluga, false killer whale, Risso's dolphin, tucuxi, Pacific white-sided dolphin, striped dolphin, and Gervais' beaked whale. Audiograms, both behavioral and AEP, for high-frequency cetaceans include those for harbor porpoise, Amazon River dolphin, Chinese river dolphin, and finless porpoise. Audiograms, both behavioral and AEP, for pinnipeds in water, include those for California sea lion, northern fur seal, northern elephant seal, harp seal, harbor seal, gray seal, Hawaiian monk seal, harp seal, and ringed seal. Audiograms, both behavioral and AEP, for pinnipeds in air, include those for northern fur seal, California sea lion, northern elephant seal, harp seal, and harbor seal. The audiograms and supporting technical data are provided in Richardson et al. (1995), Nedwell et al. (2004), Southall et al. (2007), Au and Hastings (2008), Houser et al. (2008), Kastelein et al. (2009), and Mulsow and Reichmuth (2010).

Despite the increased interest in characterizing the auditory system of beaked whales, direct data on their biosonar receiving systems are sparse. Cook et al. (2006) measured AEPs in a stranded juvenile Gervais' beaked whale between 5 and 80 kHz (lowest and highest frequencies tested, respectively). Cook et al. found that the beaked whale was most sensitive to high frequency signals between 40 and 80 kHz. At 5 kHz, there was a detectable evoked potential (EP) at an SPL of 132 dB RL, meaning that the behavioral threshold of the Gervais' beaked whale would be lower than 132 dB SPL (Cook et al., 2006). Finneran et al. (2009) used AEP measurements to determine the upper cutoff frequency of hearing in a stranded adult Gervais' beaked whale. It was determined to be 80 to 90 kHz, which is substantially lower than that seen in dolphins (~120 to 150 kHz), but similar to killer whales. The hearing sensitivities measured by Cook et al. (2006) at 5 kHz are similar to or less than those of bottlenose dolphins, and do not support the hypothesis that these species have particularly high sensitivity at the frequencies used by MFA sonar. There has been research into the procedures for audiograms, especially relating to the refinement of techniques for AEP methods and interpretation of results (Houser and Finneran, 2006; Finneran et al., 2007; Finneran, 2008, 2009; Mooney et al., 2009a).

6.2.1 Permanent Loss of Hearing

PTS is defined as the deterioration of hearing due to prolonged or repeated exposure to sounds that accelerate the normal process of gradual hearing loss (Kryter, 1985) and the permanent hearing damage from brief exposure to extremely high sound levels (Richardson et al., 1995). PTS results in a permanent elevation in hearing threshold—an unrecoverable reduction in hearing sensitivity (Southall et al., 2007). Therefore, PTS is considered an injury.

In the 2002 Rule for SURTASS LFA sonar (NOAA, 2002b), NMFS stated that TTS is not an injury. Since the boundary line between TTS and PTS is neither clear, definitive, nor predictable for marine mammals, NMFS adopted the standard that 20 dB of threshold shift defines the onset of PTS (i.e., a shift of 20 dB in hearing threshold) (NOAA, 2002b). NMFS used this same standard in the second Final Rule (NOAA, 2007c). Southall et al. (2007) proposed injury criteria for individual LF/MF/HF marine mammals exposed to non-pulsed sound types, which included discrete acoustic exposures from SURTASS LFA sonar. The proposed injury criteria for cetaceans and pinnipeds in water are SELs of 215 dB RL and 203 dB RL, respectively. An 18-dB adjustment must be made for the longer LFA signal (nominally 60 seconds) resulting in injury criteria for SURTASS LFA sonar for LF/MF/HF cetaceans of a SEL of 197 dB RL and for pinnipeds in water an SEL of 185 dB RL. The SURTASS LFA sonar injury criterion for all marine mammals was an SPL of 180 dB RL (DoN, 2001, 2007, and 2011), which is noticeably lower and, therefore, more conservative, than the injury criteria proposed by Southall et al. (2007). Thus, the probability of SURTASS LFA sonar transmissions (with mitigation) causing PTS in marine mammals is considered negligible.

6.2.2 Temporary Loss of Hearing

In addition to the possibility of causing permanent injury to hearing, sound may cause TTS, a temporary and reversible loss of hearing that may last for minutes to days. The following physiological mechanisms may result in TTS:

1. reduced sensitivity of the sensory hair cells in the inner ear as a result of their being over-stimulated;
2. modification of the chemical environment within sensory cells;
3. displacement of certain inner ear membranes;
4. increased blood flow; and
5. post-stimulation reduction in both efferent (impulses traveling from the central nervous system to the peripheral sensory tissue) and sensory output (Kryter, 1994; Ward, 1997; Southall et al., 2007).

In the 2002 and 2007 SURTASS LFA Sonar Final Rules (NOAA, 2002b and 2007c), NMFS stated that TTS is not an injury. The duration of TTS depends on a variety of factors including intensity and duration of the stimulus. Southall et al. (2007) considered that the temporary elevation of a hearing threshold by 6 dB was a sufficient definition for TTS onset. For cetaceans, most of the published TTS data are limited to bottlenose dolphins and belugas (Finneran et al., 2000, 2002, 2005, and 2007; Schlundt et al., 2000; Nachtigall et al., 2003 and 2004).

A study of TTS in harbor porpoises used a seismic airgun as a stimulus (Lucke et al., 2009). Airguns produce an impulsive signal and have a broad frequency range but also have substantial energy in the low frequency region. A small airgun was used in proximity to the animals (between 14 to 150 m), a context that is likely to enhance behavioral responsiveness. The harbor porpoises showed a behavioral response at a RL of 174 dB re 1 µPa (peak-to-peak), which is equivalent to an SEL of 145 dB re 1 μPa^2-sec (Lucke et al., 2009). Harbor porpoise hearing was tested at a frequency of 4 kHz and TTS was detected at a RL of 199.7 dB re 1 µPa (peak-to-peak), which is equivalent to an SEL of 164.3 dB re 1 μPa^2-sec (Lucke et al., 2009). These are the lowest received sound levels that produce TTS yet reported. These data are intriguing and clearly indicate a need for additional research. Unfortunately, only one individual was tested in this study. The applicability of these results to SURTASS LFA sonar is uncertain, given the large differences in source characteristics between airguns and LFA sonar. Furthermore, LFA sonar typically operates in water deeper and further offshore than most harbor porpoise habitats. Indeed, harbor porpoises are found in only one of the SURTASS LFA sonar OPAREAS analyzed, for which zero exposures at levels >180 dB SPL were found. Nevertheless, this study indicates that further study of TTS in porpoises is warranted. Ideally, additional harbor porpoise individuals as well as additional high-frequency hearing species would be tested. If this type of results are confirmed for harbor porpoise or found in other HF hearing species, then the analyses for those species would merit revision.

In a study on the effects of noise level and duration of TTS in a bottlenose dolphin, Mooney et al. (2009a) exposed a bottlenose dolphin to octave-band noise (4 to 8 kHz) of varying durations (2 to 30 minutes) and SPL RLs (130 to 178 dB re 1 µPa). The results of the Mooney et al. study indicated that shorter-duration sound exposures often require greater sound energy to induce TTS than longer-duration exposures and also supported the trend that longer-duration exposures often induce greater amounts of TTS, which concurrently require longer recovery times.

In a controlled exposure experiment, Mooney et al. (2009b) demonstrated that MFA sonar could induce temporary hearing loss in a bottlenose dolphin (*Tursiops truncatus*). Temporary hearing loss was induced by repeated exposure to an SEL of 214 dB re 1 μPa^2-sec. Subtle behavioral alterations were also associated with the sonar exposures. At least with one odontocete species (common bottlenose dolphin), sonar can induce both TTS and mild behavioral effects; but exposures must be prolonged with high exposure levels to generate these effects. The RL used in the Mooney et al. (2009b) experiment was an SPL of 203 dB, which equates to the RL approximately 40 m (131 ft) from an MFA sonar operated at an SPL of 235 dB (SL). Mooney et al. (2009b) concluded that in order to receive an SEL of near 214 dB, an animal would have to remain in proximity of the moving sonar, which is transmitting for 0.5 sec every 24 sec over an approximately 2 to 2.5 min period, an unlikely situation.

SELs necessary for TTS onset for pinnipeds in water have been measured for harbor seals, California sea lions, and northern elephant seals. As reported by Southall et al. (2007), Kastak et al. (2005) presented comparative analysis of underwater TTS for pinnipeds. This indicated that in harbor seals, a TTS of ~6 dB occurred with a 25-min exposure to 2.5 kHz octave-band noise of 152 dB SPL (183 dB SEL); a California sea lion showed TTS-onset under the same conditions at 174 dB SPL (206 dB SEL); and a northern elephant seal under the same conditions experienced TTS-onset at 172 dB SPL (204 dB SEL). Finneran et al. (2003) exposed two California sea lions to single underwater pulses from an arc-gap transducer and found no measurable TTS following exposures of up to 183 dB SPL (215 dB SEL).

Animals suffering from TTS over longer periods of time, such as hours to days, may be considered to have a change in a biologically significant behavior, as they may be prevented from detecting sounds that are biologically relevant, including communication sounds, sounds of prey, or sounds of predators. As noted by Mooney et al. (2009a), shorter duration sound exposures can require greater sound energy to induce TTS than longer duration exposures, and longer duration exposures can induce greater amounts of TTS. In assessing the potential for LFA sonar transmissions to cause TTS, the much shorter length of the LFA signal (1 min) versus the above studies (2 to 30 min) must be considered.

This recent scientific information supports the assumptions and findings of the FEIS and FSEIS (DoN, 2001 and 2007) that the likelihood that SURTASS LFA sonar, with a SPL of 180 dB RL, may cause TTS in marine mammals is negligible. Further, mitigation measures, such as mitigation zones and shutdown protocols, as outlined in the Final 2007 Rule (NOAA, 2007), are employed where there is the potential for a marine mammal to incur TTS and prevent any animal from incurring PTS.

6.2.3 BEHAVIORAL CHANGE

The primary potential deleterious effect from SURTASS LFA sonar is change in a biologically significant behavior. The National Research Council (NRC, 2005) discussed biologically significant behaviors and possible effects and stated that an action or activity becomes biologically significant to an individual animal when it affects the ability of the animal to grow, survive, and reproduce. These are the effects on individuals that can have population-level consequences and affect the viability of the species (NRC, 2005). For military readiness activities, such as the use of SURTASS LFA sonar, Level B “harassment” under the MMPA is defined as any act that disturbs or is likely to disturb a marine mammal by causing disruption of natural behavioral patterns to a point where the patterns are abandoned or significantly altered. Behaviors include migration, surfacing, nursing, breeding, feeding, and sheltering.

The Low Frequency Sound Scientific Research Program (LFS SRP) in 1997 to 1998 provided important results on, and insights into, the types of responses of baleen whales to LFA sonar signals and how those responses scaled relative to RL and context. The results of the LFS SRP confirmed that some portion of the total number of whales exposed to LFA sonar responded behaviorally by changing their vocal activity, moving away from the source vessel, or both; but the responses were short-lived (Clark et al., 2001).

In the LFS SRP LFA sonar playback experiment (Phase II), migrating gray whales avoided exposure to LFA signals (source levels of 170 and 178 dB SPL) when the source was placed in the center of their migration corridor. Responses were similar for the 170-dB SL LFA stimuli and for the 170-dB SL 1/3rd-octave, band-limited noise with timing and frequency band similar to the LFA stimulus. However, during the LFA sonar playback experiments, in all cases, whales resumed their normal activities within tens of minutes after the initial exposure to the LFA signal (Clark et al., 2001). Essentially, the whales made minor course changes to go around the source. When the source was relocated within the outer portion of the migration corridor (twice the distance offshore), and the SL was increased to reproduce the same sound field for the central corridor playback condition, the gray whales showed little to no response to the LFA sonar source. This result stresses the importance of context in interpreting the animals’ behavioral responses to underwater sounds and demonstrates that RL is not necessarily a good predictor of behavioral impact.

The LFS SRP also conducted field tests to examine the effects of LFA sonar transmissions on foraging fin and blue whales off San Nicolas Island, California (Phase I). Overall, whale encounter rates and dive behavior appeared to be more strongly linked to changes in prey abundance associated with oceanographic parameters rather than LFA sound transmissions (Croll et al., 2001b).

In the final phase of the LFS SRP (Phase III), the effect of LFA sonar on humpback whales during the winter mating season was investigated. Both Miller et al. (2000) and Fristrup et al. (2003) published results from tests conducted with male humpback singers off the Big Island, Hawaii during which they evaluated variation in song length as a function of exposure to LFA sounds. Fristrup et al. (2003) used a larger data set to describe song length variability and to explain song length variation in relation to LFA broadcasts. In spite of methodological and sample size differences, the results of the two analyses were generally in agreement, and both studies indicated that humpback whales might lengthen their songs in response to LF broadcasts.

The Fristrup et al. (2003) results also provided a detailed picture of short-term response as compared to behavioral variation observed in the absence of the stimuli. These responses were relatively brief in duration, with all observed effects occurring within 2 hrs of the last LFA source transmission. It should be noted that these effects were not obvious to the acoustic observers on the scene, but were revealed by careful, complex post-test statistical analyses (Fristrup et al*.,* 2003). Aside from the delayed responses, other measures failed to indicate cumulative effects from LFA broadcasts, with song-length response being dependent solely on the most recent LFA transmission, and not the immediate transmission history. The modeled seasonal factors (changes in density of whales sighted near shore) and diurnal factors (changes in surface social activities) did not show trends that could be plausibly explained by cumulative exposure. Increases in song length from early morning to afternoon were the same on days with and without LFA transmissions, and the fraction of variation in song length that could be attributed to LFA broadcast was small (<10%). Fristrup et al. (2003) found high levels of natural variability in humpback song length and interpreted the whales' responses to LFA broadcasts to indicate that exposure to LFA sonar would not impose a risk of dramatic changes in humpback whale singing behavior that would have demographic consequences.

Southall et al. (2007) reviewed the relatively extensive behavioral observations of low frequency cetaceans exposed to non-pulse sources. While there are clearly major areas of uncertainty, Southall et al. concluded that the literature indicated that there were no (or very limited) responses to RLs of 90 dB to 120 dB SPL with an increasing probability of avoidance and other behavioral effects in the 120 to 160 dB SPL (RL) range.

6.2.4 MASKING

The obscuring of sounds of interest by interfering sounds, generally at similar frequencies is referred to as masking (Fletcher, 1929; Richardson et al., 1995). In humans, masking has been measured as an increase in detection threshold of the sound of interest in the presence of a masking sound (compared to the detection threshold when there is no masker). Two types of masking have been described: energetic masking and informational masking (Pollack, 1975, Watson, 2005, Kidd et al., 2007). The definitions of energetic and informational masking and their physiological mechanisms, however, continue to be debated. Energetic masking is thought to result from an interfering sound(s) within the same critical band(s) as the signal of interest. It is usually ascribed to peripheral acoustic processing; i.e., the ear itself. A definition for informational masking has been even less forthcoming, and as a default position, informational masking has often been taken to mean masking that is greater than would be predicted by energetic masking alone (Kidd et al., 2007). Informational masking is associated with uncertainty of the signal of interest (Watson, 2005) and is generally assumed to occur as a result of central neural processing that includes analytic (e.g., auditory stream segregation and discrimination) and attentive components (e.g., distraction) (Kidd et al., 2007). As a general statement, the more similar the characteristics (i.e., frequency band, duration) of a masking sound are to the sound of interest, the greater its potential for masking.

Acoustic masking from low frequency ocean noise is increasingly being considered as a threat, especially to low frequency hearing specialists such as baleen whales (Clark et al., 2009). Most underwater low frequency anthropogenic noise is generated by commercial shipping, which has contributed to the increase in oceanic background noise over the past 150 years (Parks et al., 2007). Shipping noise is primarily in the 20 to 200 Hz frequency band and is increasing yearly (Ross, 2005). Andrew et al. (2002) demonstrated an increase in oceanic ambient noise of 10 dB SPL since 1963 in the 20 to 80 Hz frequency band as sampled on the continental slope off Point Sur, California, and they ascribed this increase to increased commercial shipping. McDonald et al. (2006a) compared data sets from 1964 to 1966 and 2003 to 2004 for continuous measurements west of San Nicolas Island, California, and found an increase in ambient noise levels of 10 to 12 dB SPL in the 30 to 50 Hz band. This increase in LF background noise is likely having a widespread impact on marine mammal low frequency hearing specialists by reducing their access to acoustic information essential for conspecific communication and other biologically important activities, such as navigation and prey/predator detection. Clark et al. (2009) considered this long-term, large-scale increase in low frequency background noise a chronic impact that results in a reduction in communication space, and the loss of acoustic habitat.

6.2.4.1 Marine Mammal Behavioral Responses to Masking Sounds

Parks et al. (2007) provided evidence of behavioral changes in the acoustic behaviors of the endangered North Atlantic right whale, and the South Atlantic right whale, and suggested that these were correlated to increased underwater noise levels. The study indicated that right whales might shift the frequency band of their calls to compensate for increased in-band background noise. The significance of their result is the indication of potential species-wide behavioral change in response to gradual, chronic increases in underwater ambient noise. Di Iorio and Clark (2010) showed that blue whale calling rates vary in association with seismic sparker survey activity, with whales calling more on days with survey than on days without surveys. They suggested that the whales called more during seismic survey periods as a way to compensate for the elevated noise conditions.

Changes in behavior are not limited to low frequency species. Holt et al. (2009) measured killer whale call source levels and background noise levels in the 1 to 40 kHz band. The whales increased their call source levels by 1 dB for every 1 dB increase in background noise level. A similar rate of increase in vocalization activity was reported for St. Lawrence River belugas in response to passing vessels (Scheifele et al., 2005).

6.2.4.2 SURTASS LFA Sonar Potential for Masking

Masking effects from SURTASS LFA sonar signals will be limited for a number of reasons. First, the bandwidth of any LFA sonar transmitted signal is limited (30 Hz), and the instantaneous bandwidth at any given time of the signal is small, on the order of $\leq$10 Hz. Therefore, within the frequency range in which masking is possible, the effect will be limited because animals that use this frequency range typically use signals with greater bandwidths. Thus, only a portion of frequency band for the animal's signal is likely to be masked by the LFA sonar transmissions. Furthermore, when LFA is in operation, the LFA source is active only 7.5 to 10% of the time (based on historical LFA operational parameters), which means that for 90 to 92.5% of the time there is no risk that an animal's signal will be masked by LFA sonar. Therefore, within the area in which energetic masking is possible, any effect of LFA sonar transmissions will be minimal because of the limited bandwidth and intermittent nature of the signal, and the fact that animals that use this frequency region typically produce signals with greater bandwidth that are repeated for many hours.

Hildebrand (2005) provided a comparison of anthropogenic underwater sound sources by their annual energy output. On an annual basis, four LFA sonar systems were estimated to have a total energy output of 6.8 x 10^{11} Joules/yr. Seismic airgun arrays and mid-frequency military sonars were two orders of magnitude greater, with an estimated annual output of 3.9 and 2.6 x 10^{13} Joules/year, respectively. Super tankers were greater at 3.7 x 10^{12} Joules/year. Hildebrand (2005) concluded that anthropogenic sources most likely to contribute to increased underwater noise in order of importance are: commercial shipping, offshore oil and gas exploration and drilling, and naval and other uses of sonar. The use of LFA sonar is not scheduled to increase beyond the originally analyzed four systems during the next five-year regulation under the MMPA. The percentage of the total anthropogenic acoustic energy budget added by each LFA source is estimated to be 0.21% per system (or less), when other man-made sources are considered (Hildebrand, 2005). When combined with the naturally occurring and other man-made sources of noise in the oceans, the intermittent LFA signals barely contribute a measurable portion of the total acoustic energy.

6.2.5 CONCLUSIONS

The recent research provide additional support to the conclusion that broadband LF shipping noise is likely to be more detrimental to marine mammals than low duty-cycle SURTASS LFA sonar (Andrew et al., 2002; McDonald et al., 2006a; Parks et al., 2007; Clark et al., 2009). Therefore, any masking in marine mammals due to narrowband, intermittent (low duty cycle) LFA sonar signal transmissions are expected to be minimal and unlikely.

6.2.6 ESTIMATION OF THE INFLUENCE OF LFA SIGNAL WAVEFORMS

The typical LFA signal is not a constant tone but rather is a transmission of various waveforms that vary in frequency and duration. A complete sequence of sound transmissions is referred to as a wavetrain (also known as a "ping"). LFA wavetrains last between 6 and 100 sec with an average length of 60 sec. Within each wavetrain the duration of each continuous frequency sound transmission is no longer than 10 sec. Questions have been raised concerning the characteristics of the transmitted LFA waveform type (i.e., whether the signal is a CW that is a single frequency or a FM waveform—one that sweeps through a range of frequencies), could potentially affect marine mammals differently. To date, no specific scientific investigation has been made into this question, and there are no known papers that directly compare the results of various waveforms with potential impacts.

Even though there have been no definitive studies comparing the potential impacts of various waveforms, it may be possible to estimate their relative potential for impact in some cases. For example, since most physiological impacts (i.e., physical injury, PTS, and TTS) are understood to be directly related to the amount of acoustic energy received and that the severity of the injury increases with increased levels of exposure, it seems probable that auditory impacts for FM waveforms may occur at higher received levels than for CW waveforms because the FM waveforms distribute their energy over a larger frequency band. Thus, any particular frequency-dependent portion of their hearing (e.g., specific frequency bins/regimes or anatomical devices like ear hairs or bones that hear those frequency regimes) may have received less energy in their operational hearing range and therefore have less impact or damage. However, only future testing will confirm this estimation.

For non-physiological impacts such as behavioral or masking effects, the answer is more complex and less clear. In these cases, many factors like: 1) the frequency range of the signal; 2) how the signal's frequency range overlaps with an animal's hearing and transmitted signal ranges; 3) how directional the animal's hearing is at these frequencies; 4) the degree of similarity between the received signal and possible prey species' transmissions; 5) the physical orientation of the situation; and 6) many other factors, can and will affect the level of behavior or masking impacts. Therefore, there is no simple answer to this question for these cases, and depending on the situation, an FM transmission could cause either more or less impact to a marine mammal than a CW waveform.

The Low Frequency Sound Scientific Research Program (LFS SRP) in 1997 and 1998 utilized the commonly used LFA wavetrains with no discernable differences in behavior attributed to differences in waveforms. The LFA analyses are based on the LFA risk continuum, which was based on the results of the LFS SRP. Therefore, even though the LFA signals will vary within a wavetrain, any differences in potential effects have been accounted for in the risk assessments.

6.3 POTENTIAL FOR MORTALITY: MARINE MAMMAL MASS STRANDING AND UNUSUAL MORTALITY EVENTS[12]

Stranding occurs when marine mammals passively (unintentionally) or purposefully come ashore either alive, but debilitated or disoriented, or dead. Although some species of marine mammals, such as pinnipeds, routinely come ashore during all or part of their life history, stranded marine mammals are differentiated by their helplessness ashore and inability to cope with or survive their stranded situation (i.e., they are outside their natural habitat and survival envelope) (Geraci and Lounsbury, 2005). In the U.S., the MMPA defines a stranding as: a) a marine mammal is dead and is (i) on a beach or shore of the

12 Unusual mortality events (UMEs) are a type of stranding event(s) in which several to hundreds of marine mammals die under unusual circumstances.

U.S.; or (ii) in waters under the jurisdiction of the U.S. (including any navigable waters); or b) a marine mammal is alive and is (i) on a beach or shore of the U.S. and is unable to return to the water; (ii) on a beach or shore of the U.S. 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 U.S. (including any navigable waters) but is unable to return to its natural habitat under its own power or without assistance (16 U.S. Code §1421h).

Strandings of multiple marine mammals or mass strandings, however, occur only rarely. A mass stranding of marine mammals is the stranding of two or more unrelated cetaceans (i.e., not a mother-calf pair) of the same species coming ashore at the same time and place (Geraci and Lounsbury, 2005). Mass strandings typically involve pelagic odontocete marine mammal species that occur infrequently in coastal waters and are usually typified by highly developed social bonds. Marine mammal strandings and mortality events are natural events that have been recorded historically from as early as 350 B.C. (Aristotle, ca. 350 B.C.), and such events continue to occur throughout the world's oceans.

While anthropogenic factors are responsible for some marine mammal strandings and mortality, the vast majority of causative factors are natural in origin. Mass strandings can rarely be attributed to one cause; instead, it is usually a complex series of conditions, factors, and behaviors that result in marine mammals coming ashore and dying. However, the causes of unusual mortality events (UMEs) are often attributable to one specific factor, such as an algal bloom of toxic-producing phytoplankton, or malnutrition. Even for UMEs, the likelihood of discerning the cause of a mortality event is not a surety. For instance, of the 45 UMEs that occurred in the U.S. over a 17-year period, causes could only be verified for 24 of those events, with most of the identifiable events being caused by biotoxins or infections (NMFS, 2009).

Over the last four decades, marine mammal stranding networks have become established, and the reporting of marine mammal stranding and mortality events has become better documented and publicized. This has led to increased public awareness and concern, especially regarding the potential for anthropogenic causes of stranding and mortality events. Underwater noise, particularly sounds generated by military sonar or geophysical and geologic seismic exploration, has increasingly been implicated as the plausible cause for marine mammal mortality and stranding events. However, despite extensive and lengthy investigations and continuing scientific research, definitive causes or links are rarely determined for the vast majority of marine mammal mass strandings and UMEs. It is generally more feasible to exclude causes of strandings or UMEs than to resolve the specific causative factors leading to these events. For instance, although no definitive cause could be identified for the mass stranding and death of 26 common dolphins in the Cornwall region of the United Kingdom during 2008, more than 10 factors were excluded or were considered highly unlikely to have caused the stranding (Jepson and Deaville, 2009). More detail on this stranding event follows.

Given the difficulty in correlating causative factors to marine mammal stranding and mortality events, it is imperative that assumptions not be made about the cause of these events prior to thorough investigations and analyses being conducted on all the physical evidence and associated factors. As a result of such scientific investigations and research over the last decade, especially on beaked whales, the scientific understanding has increased regarding the association between behavioral reactions to natural as well as anthropogenic sources and strandings or deaths of marine mammals. Scientists now understand that for some species, particularly deep-diving marine mammals, behavioral reactions may begin a cascade of physiologic effects, such as gas and fat embolisms, that may result in injury, death, and strandings of marine mammals (Fernández et al., 2005; Cox et al., 2006; Zimmer and Tyack, 2007).

Since strandings of individual marine mammals occur routinely around the world, only the more rarely occurring mass stranding events are documented here, particularly those that potentially could be associated with the use of military active sonar. The SURTASS LFA Sonar FSEIS (DoN, 2007) covered global mass strandings of marine mammals through 2005, and, as such, stranding data through 2005 is incorporated by reference herein. This document covers only those global mass stranding events that have occurred from 2006 through early 2010. Although the documentation process for this analysis has endeavored to be as comprehensive as possible, some mass stranding events may have been missed. No worldwide agency, organization, or group compiles or maintains a database of global mass stranding information and some local or regional mass stranding events are probably not well publicized and may have been missed, especially if they occur in remote geographic locations.

Globally from 2006 through early 2010, at least 27 mass strandings of 11 marine mammal species occurred. For this impact assessment, these 27 mass stranding and mortality events were researched and analyzed to substantiate if any occurred within or near SURTASS LFA sonar operating areas, or if any were potentially associated with the transmission of underwater sound from military sonar. Any mass strandings involving beaked whales were also examined, as strandings of this species group have been shown to have a significant correlation with MFA naval sonar activities in some geographic regions (in the Mediterranean and Caribbean Seas but not off the coasts of Japan or Southern California) (Filadelfo et al., 2009). Additionally, marine mammal stranding records from Japan were analyzed for spatial or temporal correlations to LFA sonar operations.

6.3.1 MARINE MAMMAL STRANDINGS NEAR SURTASS LFA SONAR OPERATING AREAS

6.3.1.1 2009 Philippines Stranding Events

Of the 27 global, mass stranding events from 2006 through early 2010, only one event occurred near any of the SURTASS LFA sonar operating areas. In February of 2009, as many as 200 melon-headed whales, live and dead, stranded in the shallow waters of the Bataan Peninsula near the mouth of Manila Bay in the Philippines. Few of the stranded whales died, with most surviving after having been refloated and returned to deeper water. Manila Bay and the stranding site are located on the western or South China Sea side of Luzon Island, Philippines. In March 2009, another mass stranding of 100 to 200 live melon-headed whales occurred in the Philippines, off Odiongan in Romblon. Aragones et al. (2010) attributes these mass strandings in the Philippines possibly to the illegal practice of dynamite fishing or to the strong upwelling and longshore currents produced during the northeast monsoon season. Credible informants confirmed that several fishing operations used dynamite to stun pelagic fishes in the deep waters offshore of the Zambales and Bataan provinces the night prior to the February 2009 mass stranding in Bataan (Aragones et al., 2010). The acoustic trauma associated with being in proximity to dynamite blasts in deep water may have resulted in the stranding of the melon-headed whales. Aragones et al., (2010) also found that strandings over an 11-year period in the Philippines peaked during the northeast monsoon season, which occurs from November through March.

Prior to and during the February and March 2009 stranding events, neither of the LFA sonar vessels, which are stationed in the northwestern Pacific, was actively transmitting. The last active LFA sonar transmission prior to the February stranding event occurred in December 2008 in a body of water isolated from the South China Sea.

6.3.1.2 Japanese Stranding Records

The Natural Museum of Nature and Science (NMNS) of Tokyo supports a database of marine mammal strandings, which provides marine mammal stranding records (only the species and date of strandings), for all Japanese prefectures through 2008 (NMNS, 2009). Although SURTASS LFA sonar vessels do not operate in proximity to Japanese coastal waters, a review of the stranding records from the coastal prefectures that could have potentially been exposed to LFA sonar transmissions was conducted. Sufficient data were not available to perform a quantitative analysis of the Japanese stranding data in conjunction with the dates of LFA sonar transmissions in the region adjacent to Japanese waters, but a qualitative analysis was conducted. Stranding records from 2006 through 2008 for periods of up to seven days following LFA sonar transmissions offshore from Japan were reviewed. The results of this qualitative analysis indicated that no increase in the stranding rate was associated with the periods when LFA sonar transmissions were occurring offshore from eastern Japan compared to periods when LFA sonar was not transmitting. Strandings that occurred during sonar transmissions to seven days after transmissions ceased were no higher than periods when LFA sonar was not transmitting. There were at least nine periods when LFA sonar was transmitting when no strandings occurred. In addition, in some prefectures, only very shallow water species such as finless porpoises ever stranded. These species occur inshore or in coastal waters and are unlikely to be exposed to LFA sonar transmissions.

6.3.2 Strandings Possibly Involving Military Sonar or Beaked Whales

Of the 27 mass stranding events that occurred globally from 2006 through early 2010, only two were possibly linked to military sonar transmissions with just one of those events involving beaked whales.

6.3.2.1 Spain (2006)

On January 26 through 27, 2006, four Cuvier's beaked whales were reported stranded along the southeast coast of Spain near Almeria in the western Mediterranean Sea. Of the four stranded beaked whales, two live-stranded while the remaining two whales were dead when discovered. All the whales ultimately died. Necropsies were performed on all four of the whales. Although the pathologists that conducted the necropsies concluded that anthropogenic acoustic activities were the likely cause of the whales stranding, no pathological results supporting this conclusion were ever presented, and no further documentation has been published.

A North Atlantic Treaty Organization (NATO) surface ship group (seven ships including one U.S. ship under NATO command) conducted active sonar training against a Spanish submarine target from January 25 through 26, 2006 in the Cartagena Exercise Area, which is located within 93 km (50 nmi) of the stranding sites. Although no definitive pathological or causal linkage between the naval exercises and the mass stranding has been documented, it appears likely that a confluence of factors such as: 1) the water depths in which the naval exercises occurred (1,000 m [3,281 ft] with steeply grading slope); 2) the multiple ships equipped with MFA sonar operating in proximity within the same area for a long duration (~20 hrs); and 3) the topography of the area in which deep water is surrounded by land masses that may have caused sound to be directed toward a channel or embayment, cutting off the whales' egress, may have contributed to the strandings of the Cuvier's beaked whales. As presented in Dolman et al. (2010), Fernandez (2006) concluded that the Almeria strandings were similar to previous atypical mass strandings of beaked whales that were spatially and temporally associated with military naval sonar exercises, such as in the Bahamas (2000) and the Canary Islands (2002).

6.3.2.2 Cornwall, United Kingdom (2008)

On June 9, 2008, 26 common dolphins died after mass stranding in a small tidal tributary, Porth Creek, of the Fal Estuary in Cornwall, southwestern England. An even larger number of common dolphins were refloated and herded back into deeper water. In the days preceding the mass stranding, a large group(s) of dolphins was observed very close to shore. All of the dead stranded dolphins were necropsied; and detailed pathological, histological, and other diagnostic testing was conducted, as was an investigation of the area, environmental conditions, and interviews with witnesses and responders.

An international naval exercise was conducted in the South Coast Exercise Area, located off the south coast of Cornwall, Devon, and Dorset, from 1 through 9 June, 2008 with peak activity on 4 to 5 June. The naval exercise involved up to 20 Royal Navy (United Kingdom) surface and submarine vessels as well as 11 international ships (Jepson and Deaville, 2009). The joint exercise involved the use of several acoustic sources, including MFA (2 to 8 kHz) sonar, standard echosounders, acoustic modems, sonobuoys, high-frequency (100 kHz) side-scan sonar; the firing of inert and live ammunition and at least one SEAWOLF missile, and helicopter and fixed-wing aircraft flights. No helicopter or fixed-wing flights occurred over the area of the mass stranding. The MFA sonars were employed at least 45 to 50 km (24 to 27 nmi) from the stranding location. Approximately 60 hours lapsed between the end of MFA sonar transmissions and the mass stranding event.

The results of the investigation of this mass stranding event were reported by Jepson and Deaville (2009); the pathological and other analysis results were presented with no finding of significant infectious disease, contaminants, biotoxins, or acute physical injury in the dead dolphins. The ears of all the dolphins were normal with no damaged tissue. Jepson and Deaville (2009) concluded that the following potential causes for the stranding could be excluded or were considered highly unlikely to have caused the mass stranding: infectious disease, fat or gas embolisms (decompression sickness), boat strike, fisheries bycatch, predation, feeding unusually close to shore, ingestion of biotoxins or harmful contaminants, abnormal weather conditions, and high-intensity underwater acoustic sound from airguns or earthquakes. While no definitive cause could be identified for the mass stranding event, the investigation did conclude that an adverse behavioral reaction to some specific trigger or stimuli within a group of healthy dolphins resulted in the mass stranding and death of the 26 common dolphins (Jepson and Deaville, 2009). The investigation also noted that the dolphin's unusual proximity to shore prior to the mass stranding, or a combination of factors including errors in navigation and other natural or anthropogenic factors, could have led to an increased risk of stranding. While the investigators did acknowledge that the use of the MFA sonar could have led to the dolphins being closer to shore than normal, they considered it highly unlikely that the MFA sonar directly triggered the mass stranding event (Jepson and Deaville, 2009).

6.3.3 CONCLUSIONS—MARINE MAMMAL MASS STRANDING AND UNUSUAL MORTALITY EVENTS

The use of SURTASS LFA sonar was not associated with any of the reported 27 mass stranding events or UMEs that occurred globally between 2006 and early 2010. There is no evidence that LFA sonar transmissions resulted in any difference in the stranding rates of marine mammals in Japanese coastal waters adjacent to LFA sonar operating areas. As has been reported previously (DoN, 2001 and 2007a) and has been further documented here, the employment of LFA sonar is not expected to result in any sonar-induced strandings of marine mammals. Given the large number of natural factors that can result in marine mammal mortality, the high occurrence of marine mammal strandings, and the many years of LFA sonar operations without any reported associated stranding events, the likelihood of LFA sonar transmissions causing marine mammals to strand is negligible. In summary, from the commencement of SURTASS LFA sonar in 2002 through the present, the sonar has not been associated with any global mass stranding of marine mammals.

6.3.4 POTENTIAL IMPACTS ON MARINE MAMMALS—CONCLUSIONS

The potential effects from SURTASS LFA sonar operations on any stock of marine mammals from injury (non-auditory or permanent loss of hearing) are considered negligible, and the potential effects on the stock of any marine mammal from temporary loss of hearing or behavioral change (significant change in a biologically important behavior) are considered minimal. Employment of SURTASS LFA sonar will have a negligible impact on marine mammals because:

- Potential effects on marine mammal species or stocks are expected to be limited to Level B harassment. The Navy does not expect those effects to impact rates of recruitment or survival on the associated marine mammal species and stocks. Thus, effects on recruitment or survival are expected to be negligible.
- Navy's impact analysis does not anticipate any mortality nor any injury of marine mammals to occur as a result of LFA sonar operations, and the potential to cause strandings of marine mammals is negligible.
- Potential for injury to sea turtles and fish is negligible.
- Potential for non-injurious effects (TTS, masking, modification of biological important behavior) is minimal to negligible.
- Cumulative effects are not a reasonably foreseeable adverse impact, as auditory masking potentially resulting from the SURTASS LFA sonar contribution to cumulative effects on oceanic ambient noise levels would only occur over a very small spatial and temporal scale, due in large part to the small number of possible sonar systems operating (no more than four worldwide). The cumulative effects

related to the potential for masking from the potential four SURTASS LFA sonar systems are not a reasonably foreseeable significant adverse impact on marine animals.

Further, SURTASS LFA sonar has been operating since 2003, and no marine mammal stranding events have ever been associated with employment of the sonar. No mass strandings have occurred in the areas in which the sonar has operated. Thus, the likelihood of LFA sonar transmissions causing marine mammals to strand is negligible.

6.4 RISK ASSESSMENT OF POTENTIAL IMPACTS ON MARINE MAMMALS FROM SURTASS LFA SONAR OPERATIONS

The goal of the risk assessment is to analyze the activity of the U.S. Navy employing up to four SURTASS LFA sonar systems for routine training, testing, and military operations in the oceanic areas. Based on current operational requirements, exercises using these sonar systems could occur in the Pacific, Atlantic, and Indian Oceans, and the Mediterranean Sea. To reduce adverse effects on the marine environment, areas would be excluded as necessary to prevent 180-dB SPL or greater within a specific geographic range of land and in OBIAs during biologically important seasons and to prevent greater than 145-dB SPL at known recreational and commercial dive sites.

Risk assessments must provide decision-makers and regulators results that demonstrate:

- Under the MMPA, the least practicable adverse impacts on marine mammals while including consideration of personnel safety, practicability of implementation, and impact on the effectiveness of military readiness activities; and
- Under the ESA, employment of SURTASS LFA sonar is not likely to jeopardize the continued existence of threatened/endangered marine species or adversely affect critical habitats.

Since it was neither reasonable nor practicable to model all areas of the world's oceans in which SURTASS LFA sonar could operate, the initial risk assessment in the SURTASS LFA Sonar FOEIS/EIS (DoN, 2001) analyzed 31 potential operating sites. This initial analytical process was refined to provide sensitivity and risk analyses sufficient to identify and select potential SURTASS LFA sonar mission areas with minimal marine mammal/animal activity consistent with the Navy's operational readiness requirements. These analyses were used to provide NMFS with reasonable and realistic pre- and post-operational risk estimates for marine mammal stocks in the proposed SURTASS LFA sonar operating areas. This process was documented in the SURTASS LFA Sonar FSEIS (DoN, 2007).

In the analysis for the Draft SEIS/SOEIS (DoN, 2011), 19 additional operating sites have been analyzed. These sites were chosen because they represent, based on today's political climate, areas where SURTASS LFA sonar could potentially test, train, or operate during the 5-year period of the next MMPA Rule.

6.4.1 MARINE MAMMAL IMPACT ANALYSIS

As previously discussed, the types of potential effects on marine mammals from SURTASS LFA sonar operations include: 1) non-auditory injury; 2) permanent loss of hearing; 3) temporary loss of hearing; 4) behavioral change; and 5) masking. The first two potential effects (i.e., non-auditory physical effects and permanent loss of hearing) are typically grouped together and constitute "injury effects" or Level A harassments as defined in the MMPA. Based on Southall et al. (2007) and adjusting for the longer LFA signal, the proposed injury criteria for SURTASS LFA sonar of a sound exposure level (SEL) of 197 dB received level (RL) for cetaceans. For pinnipeds in water, this adjusted value would be an SEL of 185 dB RL. Please note that due to the long duration of the LFA signal (i.e., nominally 60 seconds), the SEL criteria from Southall et al. (2007) is always the dominant of the dual criteria identified there. Additionally, based on simple spherical spreading (i.e., a transmission loss [TL] based on 20×Log10 [range in meters]) and assuming that the LFA array is a point source, a cetacean would need to approach and remain within approximately 8 m (26 ft) of the LFA source array (while a pinniped would need to be within 32 m [105 ft] of the array) for the complete 60 sec of the transmission to exceed the Southall et al. (2007) injury thresholds. Based on the mitigation procedures used during LFA sonar operations, the chances of this occurring are negligible. Therefore, no Level A harassment under the MMPA is expected.

The next two potential effects listed above (temporary loss of hearing and behavioral change) are also typically grouped together and constitute “non-injury or harassment effects” or Level B harassments as defined in the MMPA. The underlying scientific studies and reports that are documented earlier in this chapter show that the potential impacts to marine mammal hearing varies not only from species to species, but may also vary from animal to animal within a species. Thus, the utilization of a risk continuum to attempt to capture the variability of acoustic impacts to a species, as was first done for U.S. Navy environmental compliance documents in the SURTASS LFA FOEIS/EIS (DoN, 2001), has become the standard approach for the U.S. Navy (further details regarding the risk continuum methodology may be found in Appendix C of the Draft SEIS/SOEIS [DoN. 2011]). The risk continuum function is a means of predicting the potential impacts associated with acoustic operations on marine mammal species near the operational area of sonar systems. The inputs to the risk continuum are typically the amount of acoustic exposure an animal is likely to receive during the proposed operation. To estimate the risk to marine mammals in each of the 19 potential operating areas, a list of marine mammals likely to be encountered in each region was developed and abundance and density estimates calculated for each species at each potential SURTASS LFA sonar operating area. To determine the likely acoustic exposure, the movement of animals in the area is modeled, along with the acoustic field generated by the sonar system. Acoustic impact modeling of 19 potential SURTASS LFA sonar-operating areas was conducted for this SEIS/SOEIS, resulting in estimated percent harassment for each stock. The fifth potential effect on marine mammals from SURTASS LFA sonar operations is masking; this topic has been covered previously in this chapter.

6.4.2 INITIAL RISK ASSESSMENT OF POTENTIAL IMPACTS TO MARINE MAMMALS

The initial risk assessment of potential impacts to marine mammals from the operation of SURTASS LFA sonar was detailed in the SURTASS LFA Sonar FOEIS/EIS (DoN, 2001); this detailed analysis covered the major oceanic regions of the world and analyzed 31 acoustic modeling sites. Marine mammal data were developed from the most recent NMFS stock assessment reports at the time and pertinent multinational scientific literature containing marine mammal distribution, abundance, and/or density datasets. The locations were chosen to represent reasonable sites for each of the three major underwater sound propagation regimes where SURTASS LFA sonar could be employed and included:

- Deep water convergence zone (CZ) propagation;
- Near surface duct propagation; and
- Shallow-water bottom interaction propagation.

These sites were selected to model the highest potential (upper bound) for effects from the use of SURTASS LFA sonar, incorporating the following factors:

- Closest plausible proximity to land (from the standpoint of SURTASS LFA sonar operations) where biological densities were higher, and/or were offshore biologically important areas (particularly for animals most likely to be affected);
- Acoustic propagation conditions that allow minimum propagation loss, or TL (i.e., longest acoustic transmission ranges); and
- Time of year selected for maximum animal abundance.

These sites represented the upper bound of effects (both in terms of possible acoustic propagation conditions, and in terms of marine mammal population and density) that could be expected from operation of the SURTASS LFA sonar system. In other words, the analyses of these 31 sites could be considered “worst-case” scenarios. Thus, if SURTASS LFA sonar operations were conducted in an area that was not acoustically modeled in the FOEIS/EIS and was lower in marine mammal abundances and densities, the potential effects would most likely be less than those obtained from the most similar site in the analyses presented. Effectively, these conservative assumptions of the 2001 FOEIS/EIS are still valid.

6.4.3 Sensitivity/Risk Assessment Approach

Under the first MMPA Rule (NOAA, 2002b) and 2007 MMPA Rule (NOAA, 2007c), the Navy was required to apply for initial LOAs (50 CFR §216.187, 2007) and annual renewals of LOAs (50 CFR §216.189, 2011). In these applications, the Navy projected where it intended to operate for the period of the next annual LOAs and provided NMFS with reasonable and realistic pre-operational risk estimates for marine mammal stocks in the proposed mission areas. The LOA application analytical process for risk assessment was described in the SURTASS LFA Sonar FSEIS (DoN, 2007a). This risk assessment was developed based on the analyses in the SURTASS LFA Sonar FOEIS/EIS (DoN, 2001), the process utilized for the initial annual applications for LOAs, updated literature reviews, and additional underwater acoustical modeling. This sensitivity/risk process utilized a conservative approach by integrating mission planning needs (Navy's training and operational ASW requirements) and a cautious assessment of the limited data available on specific marine mammal populations, and seasonal habitat and activity. Mission areas were analyzed based on current scientific data to determine the potential sensitivity of marine mammals to SURTASS LFA sonar signals and risks to their stocks. Species-specific density and stock abundance estimates were derived for the selected mission areas from current, available published source documentation.

The process begins with the Navy's ASW requirements to be met by SURTASS LFA sonar based on mission areas proposed by the Chief of Naval Operations (CNO) and fleet commands (Figure 4). Thereupon, available published data are collected, collated, reduced and analyzed with respect to marine mammal populations and stocks, marine mammal habitat and seasonal activities, and marine mammal behavioral activities. Utilizing the best available scientific data, estimates are made by highly qualified marine biologists, based on known data for like species and/or geographic areas, and known marine mammal seasonal activity. If marine mammal densities prove to be high and/or sensitive animal activities are expected, the mission areas are changed and/or refined to areas with lower numbers of marine mammals, or lower levels of sensitive marine mammal activities. Subsequently the process is re-initiated for the modified mission area. Next, standard acoustic modeling and risk analyses are performed, taking into account spatial, temporal, and/or operational restrictions. Then, standard mitigation is applied and risk estimates for marine mammal stocks in the proposed mission area are calculated. Based on these estimates, a decision is made as to whether the proposed mission area meets the conditions of the MMPA regulations and LOAs, as issued, on marine mammal/animal impacts from SURTASS LFA sonar. If not, the proposed mission area is changed or refined, and the process is re-initiated. If the mission area risk estimates are below the required restrictions, then the Navy has identified and selected the potential mission area with minimal marine mammal/animal activity consistent with its operational readiness requirements and restrictions placed on LFA operations by NMFS in the regulatory and consultation processes. This sensitivity/risk assessment approach allows the Navy to determine where and when SURTASS LFA sonar can operate and meet the MMPA condition for the least practicable adverse impacts on marine mammals.

Over the 5-year period of the 2002 MMPA Rule, some of the data gaps were filled, reducing the number of assumptions that necessarily must be made during this analytical process. This type of practical analysis clearly demonstrated that the operation of SURTASS LFA sonar systems under annual LOAs satisfied the regulatory requirement to assess environmental risk to marine mammal stocks for the annual LOAs under the first 5-year Rule (2002 to 2007) and the first three annual LOA periods under the current Rule (2007 to 2012). Under the 2007 Rule and LOAs, NMFS has provided regulations and conditions to ensure that the incidental taking of marine mammals resulting from SURTASS LFA sonar operations would have negligible impacts on the affected marine mammal species or stocks. The Navy uses these regulations and conditions as guides in mission planning and annual LOA applications.

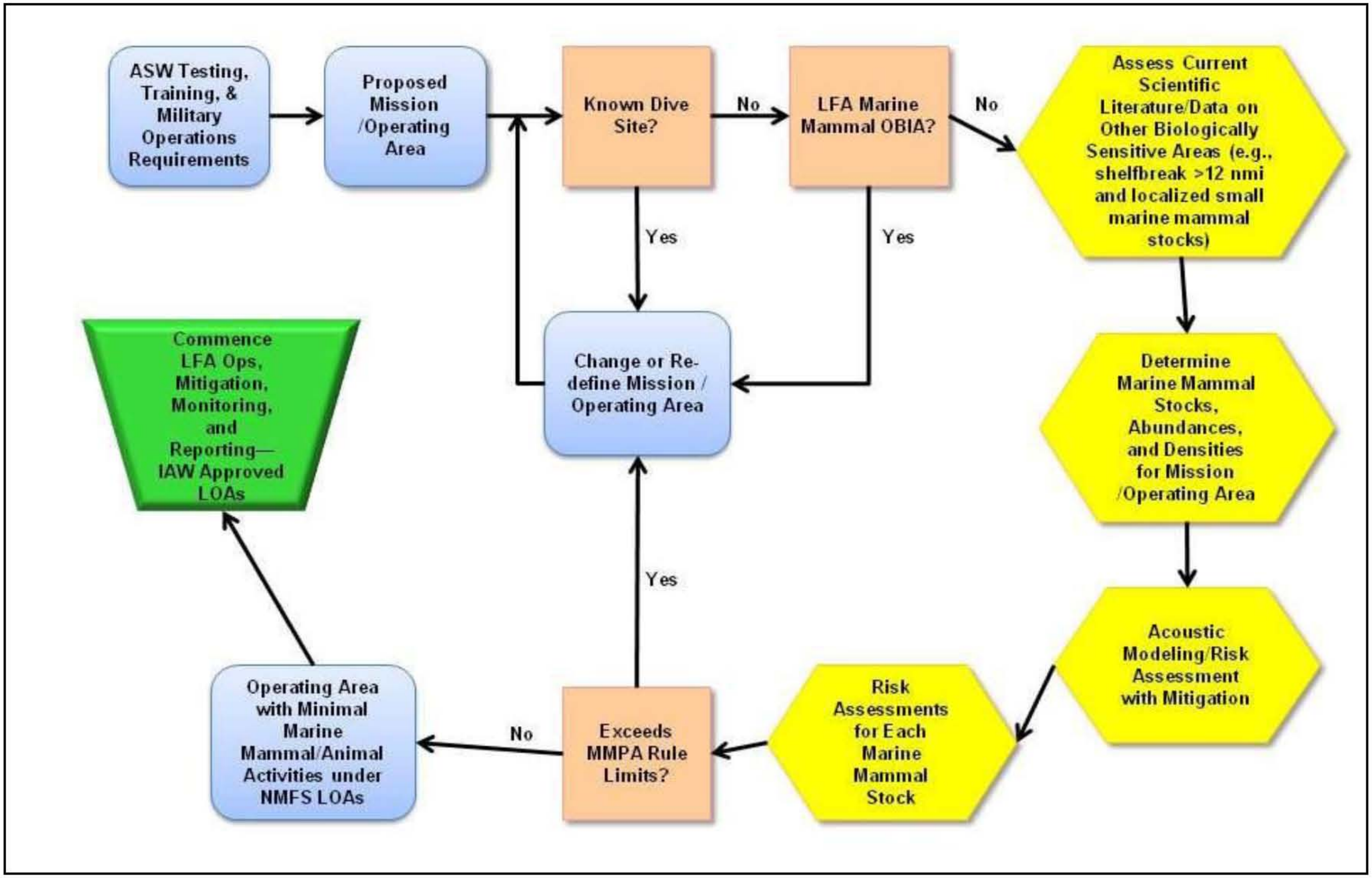


Figure 4. Overview of the SURTASS LFA sonar sensitivity/risk assessment approach.

The Navy is required under the conditions of the 2007 and annual LOAs to submit classified quarterly mission reports for each SURTASS LFA sonar vessel for missions completed during the quarter in which active LFA transmissions are employed. The required elements for these reports include estimates of the percentage of marine mammal stocks affected (both for the quarter and cumulative for the year covered by the LOAs) by SURTASS LFA sonar operations based on predictive modeling, and actual operating locations, dates/times of operations, system characteristics, oceanographic environmental conditions, and animal demographics. The total annual risks for potentially affected stocks of marine mammal species are estimated by summing a particular species' risk estimates within each stock, across mission areas, for all vessels combined and are submitted to NMFS in annual unclassified reports. For the first three LOAs under the 2007 rule, the Navy has conducted the specified activities in the manner described in the 2007 regulation and annual LOAs, and has implemented the required mitigation and monitoring measures (Tables 6, 7, and 8). Additionally, marine mammal detections and behavioral observations suggest that the actual impacts of SURTASS LFA sonar operation and training fall within the scope and nature of those analyzed and anticipated by the 2007 regulation and LOAs (i.e., the Navy has not exceeded the take authorized by NMFS in the 2007 regulation or LOAs).

6.4.4 SUPPLEMENTAL RISK ASSESSMENTS

The sensitivity/risk process, discussed above, utilizes a conservative approach by integrating mission planning needs (Navy's training and operational ASW requirements), a cautious assessment of the limited data available on specific marine mammal populations, and seasonal habitat and activity. In this supplemental analysis, 19 additional operating sites have been analyzed using the most up-to-date marine mammal abundance, density, and behavioral information available (see Table 3). These sites were chosen because they represent, based on today's political climate, areas where SURTASS LFA sonar could potentially test, train, or operate. This analysis will provide updated modeling for the 11 sites under the 2007 regulation and LOAs and eight additional sites, which could be requested for LOAs under the next 5-year Rule because they are in areas of potential strategic importance and/or areas of possible Fleet exercises.

The Navy will use the same risk continuum function for estimating acoustic impacts in this document that was used in the Final EIS/OEIS and Final SEIS for SURTASS LFA sonar (DoN, 2001, 2007). The inputs to the risk continuum are typically the amount of acoustic exposure an animal is likely to receive during the proposed operation. To determine the likely acoustic exposure, the movements of animals in the area are modeled along with the acoustic fields generated by the sonar systems.

The Acoustic Integration Model© (AIM) was used to simulate and integrate potential acoustic effects of SURTASS LFA sonar operations. The sound fields produced by the LFA source in the different areas were modeled based on the system's specifications (i.e., source level, frequency, and location of the sonar system). Details of the physical acoustic environment as well as details of marine species' presence and their movement come from numerous sources. AIM convolves the sound field data generated by an acoustic model with animal movement data generated from an animal movement engine. The result is an exposure history for each simulated animal (animat); i.e., as if each animal was fitted with an "acoustic dosimeter." These exposure data for individually modeled animats are then scaled and summed to predict the risk of impact for each animal species.

Estimates of the percentage of marine mammal stocks affected by SURTASS LFA sonar operations in the 19 potential operating areas, for the seasons specified, have been derived for this document (Tables 9 through 27). The estimated percentages of stocks affected with the implementation of mitigation measures supports the conclusion that estimates of potential effects to marine mammal stocks are below the conditions delineated by NMFS in the LOAs issued under the 2007 Final Rule (NOAA, 2007). Additionally, SURTASS LFA sonar has been operating since 2003 in the northern Pacific Ocean with no reported injuries (Level A (MMPA) harassment), serious injuries, or mortalities associated with its operations (DoN, 2008; 2009b; 2010).

Table 6. Post-operational estimates of marine mammal stocks potentially affected by operation of SURTASS LFA sonar in all mission areas—totals for the 2007 LOA; ESA-listed species indicated by blue highlighting.

LOA 1—R/V CORY CHOUEST & USNS IMPECCABLE				
MARINE MAMMAL SPECIES (SEASONAL OCCURRENCE)	STOCK	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED (W/ MIT[13]) 120 TO 180 DB	% STOCK AFFECTED (W/ MIT) ≥180 DB
			ANNUAL TOTAL	ANNUAL TOTAL
Fin whale	N. Pacific	9,250	0.57	0.00
Bryde's whale	Western N. Pacific	22,000	0.71	0.00
Common minke whale	Western N. Pacific	25,049	5.17	0.00
North Pacific right whale (Spring/Fall/Winter)	Western N. Pacific	922	0.17	0.00
Humpback whale (Winter only)	Western N. Pacific	394	1.48	0.00
Gray whale (Winter only)	Western N. Pacific	100	0.00	0.00
Sperm whale	N. Pacific	102,112	0.15	0.00
Kogia spp.	N. Pacific	350,553	0.09	0.00
Cuvier's beaked whale	N. Pacific	90,725	0.06	0.00
Blainville's beaked whale	N. Pacific	8,032	1.00	0.00
Ginkgo-toothed beaked whale	N. Pacific	22,799	0.37	0.00
Killer whale	Western N. Pacific	12,256	0.01	0.00
False killer whale	Western N. Pacific	16,668	2.67	0.00
False killer whale	Inshore Archipelago	9,777	0.69	0.00
Pygmy killer whale	Western N. Pacific	30,214	1.28	0.00
Melon-headed whale	Western N. Pacific	36,770	1.30	0.00
Short-finned pilot whale	Western N. Pacific	53,608	2.69	0.00
Risso's dolphin	Western N. Pacific	83,289	3.05	0.00
Common dolphin	Western N. Pacific	3,286,163	0.42	0.00
Bottlenose dolphin	Western N. Pacific	168,791	1.37	0.00
Bottlenose dolphin	Inshore Archipelago	105,138	0.70	0.00
Spinner dolphin	Western N. Pacific	1,015,059	0.01	0.00
Pantropical spotted dolphin	Western N. Pacific	438,064	0.78	0.00
Striped dolphin	Western N. Pacific	570,038	0.64	0.00
Rough-toothed dolphin	Western N. Pacific	145,729	0.84	0.00
Fraser's dolphin	Western N. Pacific	220,789	0.41	0.00
Pacific white-sided dolphin	Western N. Pacific	931,000	0.46	0.00

13 With mitigation measures applied.

Table 7. Post-operational estimates of marine mammal stocks potentially affected by operation of SURTASS LFA sonar in all mission areas—totals for the 2008 LOA; ESA-listed species indicated by blue highlighting.

LOA 2—USNS ABLE and USNS IMPECCABLE				
Marine Mammal Species (Seasonal Occurrence	Stock	Number Animals in Stock	% Stock Affected (w/ mit[14]) 120 to 180 dB	% Stock Affected (w/mit) ≥180 dB
			Annual Total	Annual Total
Blue whale	Western N. Pacific	1,548	0.33	0.00
Fin whale	N. Pacific	9,250	0.03	0.00
Fin whale	Hawaii	2,099	0.86	0.00
Bryde's whale	Western N. Pacific	22,000	0.17	0.00
Bryde's whale	Hawaii	469	1.09	0.00
Common minke whale	Western N. Pacific	25,049	1.00	0.00
Common minke whale	Hawaii	25,000	0.02	0.00
N. Pacific right whale (Spring/Fall/Winter)	Western N. Pacific	922	0.05	0.00
Humpback whale (Winter only)	Western N. Pacific	394	0.00	0.00
Gray whale (Winter only)	Western N. Pacific	100	0.00	0.00
Sperm whale	N. Pacific	102,112	0.06	0.00
Sperm whale	Hawaii	6,919	0.54	0.00
Kogia spp.	N. Pacific	350,553	0.01	0.00
Kogia spp.	Hawaii	24,657	0.54	0.00
Cuvier's beaked whale	N. Pacific	90,725	0.15	0.00
Cuvier's beaked whale	Hawaii	15,242	0.54	0.00
Longman's beaked whale	Hawaii	1,007	0.53	0.00
Blainville's beaked whale	N. Pacific	8,032	0.19	0.00
Blainville's beaked whale	Hawaii	2,872	0.54	0.00
Ginkgo-toothed beaked whale	N. Pacific	22,799	0.06	0.00
Killer whale	Western N. Pacific	12,256	0.08	0.00
Killer whale	Hawaii	349	0.56	0.00
False killer whale	Western N. Pacific	16,668	0.53	0.00
False killer whale	Inshore Archipelago	9,777	0.03	0.00
False killer whale	Hawaii	236	0.83	0.00
Pygmy killer whale	Western N. Pacific	30,214	0.22	0.00
Pygmy killer whale	Hawaii	956	0.82	0.00
Melon-headed whale	Western N. Pacific	36,770	0.12	0.00
Melon-headed whale	Hawaii	2,950	0.80	0.00
Short-finned pilot whale	Western N. Pacific	53,608	0.78	0.00
Short-finned pilot whale	Hawaii	8,870	0.80	0.00
Risso's dolphin	Western N. Pacific	83,289	0.51	0.00

14 With mitigation measures applied

Table 7. Post-operational estimates of marine mammal stocks potentially affected by operation of SURTASS LFA sonar in all mission areas—totals for the 2008 LOA; ESA-listed species indicated by blue highlighting.

LOA 2—USNS ABLE and USNS IMPECCABLE				
MARINE MAMMAL SPECIES (SEASONAL OCCURRENCE	STOCK	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED (W/ MIT[14]) 120 TO 180 DB	% STOCK AFFECTED (W/MIT) ≥180 DB
			ANNUAL TOTAL	ANNUAL TOTAL
Risso's dolphin	Hawaii	2,372	1.06	0.00
Common dolphin	Western N. Pacific	3,286,163	0.06	0.00
Bottlenose dolphin	Western N. Pacific	168,791	0.33	0.00
Bottlenose dolphin	Inshore Archipelago	105,138	0.05	0.00
Bottlenose dolphin	Hawaii	3,215	1.02	0.00
Spinner dolphin	Western N. Pacific	1,015,059	0.09	0.00
Spinner dolphin	Hawaii	3351	0.98	0.00
Pantropical spotted dolphin	Western N. Pacific	438,064	0.12	0.00
Pantropical spotted dolphin	Hawaii	8,978	0.98	0.00
Striped dolphin	Western N. Pacific	570,038	0.18	0.00
Striped dolphin	Hawaii	13,143	0.98	0.00
Rough-toothed dolphin	Western N. Pacific	145,729	0.13	0.00
Rough-toothed dolphin	Hawaii	8,709	0.98	0.00
Fraser's dolphin	Western N. Pacific	220,789	0. 07	0.00
Fraser's dolphin	Hawaii	10,226	0. 99	0.00
Pacific White-sided dolphin	Western N. Pacific	931,000	0.05	0.00
Hawaiian monk seal	Hawaii	1,302	0.24	0.00

Table 8. Post-operational estimates of marine mammal stocks potentially affected by the operation of SURTASS LFA sonar in all mission areas—totals for the 2009 LOA; ESA-listed species indicated by blue highlighting.

LOA 3—USNS ABLE & USNS IMPECCABLE				
MARINE MAMMAL SPECIES (SEASONAL OCCURRENCE	STOCK	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED (W/ MIT[14]) 120 TO 180 DB	% STOCK AFFECTED (W/ MIT) ≥180 DB
			ANNUAL TOTAL	ANNUAL TOTAL
Blue whale	North (N.) Pacific	9,250	0.03	0.00
Fin whale	N. Pacific	9,250	0.17	0.00
Sei whale	N Pacific	8,600	0.10	0.00
Bryde's whale	Western N. Pacific	22,000	0.30	0.00
Common minke whale	Western N. Pacific	25,049	1.72	0.00
N. Pacific right whale (spring/fall/winter)	Western N. Pacific	922	0.06	0.00
Humpback whale (Winter only)	Western N. Pacific	394	1.78	0.00
Sperm whale	N. Pacific	102,112	0.15	0.00
Kogia spp.	N. Pacific	350,553	0.06	0.00
Baird's beaked whale	Western N. Pacific	8,000	0.26	0.00
Baird's beaked whale	Western N. Pacific	8,000	0.26	0.00
Cuvier's beaked whale	N. Pacific	90,725	0.25	0.00
Blainville's beaked whale	N. Pacific	8,032	0.52	0.00
Ginkgo-toothed beaked whale	N. Pacific	22,799	0.20	0.00
Hubbs' beaked whale	N. Pacific	22,799	0.02	0.00
Killer whale	Western N. Pacific	12,256	0.11	0.00
False killer whale	Western N. Pacific	16,668	1.79	0.00
Pygmy killer whale	Western N. Pacific	30,214	0.71	0.00
Melon-headed whale	Western N. Pacific	36,770	0.30	0.00
Short-finned pilot whale	Western N. Pacific	53,608	2.02	0.00
Risso's dolphin	Western N. Pacific	83,289	1.57	0.00
Common dolphin	Western N. Pacific	3,286,163	0.20	0.00
Bottlenose dolphin	Western N. Pacific	168,791	1.09	0.00
Spinner dolphin	Western N. Pacific	1,015,059	0.00	0.00
Pantropical spotted dolphin	Western N. Pacific	438,064	0.39	0.00
Striped dolphin	Western N. Pacific	570,038	0.43	0.00
Rough-toothed dolphin	Western N. Pacific	145,729	0.47	0.00
Fraser's dolphin	Western N. Pacific	220,789	0. 22	0.00
Pacific white-sided dolphin	Western N. Pacific	931,000	0.24	0.00

Table 9. Estimates of the percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 1, East of Japan, summer season; ESA-listed species highlighted.

OPAREA 1—East of Japan			
Marine Mammal Species	**Number Animals in Stock**	**% Stock Affected <180 dB**	**% Stock Affected (with mitigation) ≥180 dB**
Blue whale	9,250	0.0182	0.0000
Fin whale	9,250	0.0221	0.0000
Sei whale	8,600	0.0661	0.0000
Bryde's whale	20,501	0.0277	0.0000
Common minke whale	25,049	0.0566	0.0000
North Pacific right whale (Spring/Fall)	922	< 0.0001	0.0000
Sperm whale	102,112	0.0060	0.0000
Kogia spp.	350,553	0.0079	0.0000
Baird's beaked whale	8,000	0.2603	0.0000
Cuvier's beaked whale	90,725	0.0427	0.0000
Gingko-toothed beaked whale	22,799	0.0157	0.0000
Hubbs' beaked whale	22,799	0.0157	0.0000
False killer whale (pelagic)	16,668	0.1916	0.0000
Pygmy killer whale	30,214	0.0617	0.0000
Short-finned pilot whale	53,608	0.2170	0.0000
Risso's dolphin	83,289	0.1138	0.0000
Common dolphin	3,286,163	0.0212	0.0000
Bottlenose dolphin[15]	168,791	0.0823	0.0000
Spinner dolphin	1,015,059	0.0002	0.0000
Pantropical spotted dolphin	438,064	0.0180	0.0000
Striped dolphin	570,038	0.0059	0.0000
Rough-toothed dolphin	145,729	0.0346	0.0000
Fraser's dolphin	220,789	0.0153	0.0000
Pacific white-sided dolphin	931,000	0.0070	0.0000

15 Until recently, the genus *Tursiops* was considered monospecific, but a second species (the Indo-Pacific bottlenose dolphin, *Tursiops aduncus*) is now also recognized (Rice, 1998). Indo-Pacific bottlenose dolphins generally occur over shallow coastal waters on the continental shelf or around oceanic islands. Their presence has primarily been documented in estuarine and near-coastal waters that are not likely to overlap with SURTASS LFA sonar operations. Without further information on the composition of bottlenose dolphins at the sites modeled for this document, the model results should be considered as potential impacts to *Tursiops* spp. in general.

Table 10. Estimates of the percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 2, North Philippine Sea, fall season; ESA-listed species highlighted.

OPAREA 2—NORTH PHILIPPINE SEA			
MARINE MAMMAL SPECIES	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED <180 dB	% STOCK AFFECTED (WITH MITIGATION) ≥180 dB
Bryde's whale	20,501	0.0339	0.0000
Common minke whale	25,049	0.4023	0.0000
North Pacific right whale (Spring/Fall/Winter)	922	0.0055	0.0000
Sperm whale	102,112	0.0454	0.0000
Kogia spp.	350,553	0.0265	0.0000
Cuvier's beaked whale	90,725	0.0534	0.0000
Blainville's beaked whale	8,032	0.0559	0.0000
Gingko-toothed beaked whale	22,799	0.0197	0.0000
Killer whale	12,256	0.0379	0.0000
False killer whale (pelagic)	16,668	0.2123	0.0000
Pygmy killer whale	30,214	0.0848	0.0000
Melon-headed whale	36,770	0.0398	0.0000
Short-finned pilot whale	53,608	0.5137	0.0000
Risso's dolphin	83,289	0.3337	0.0000
Common dolphin	3,286,163	0.0168	0.0000
Bottlenose dolphin[15]	168,791	0.0548	0.0000
Spinner dolphin	1,015,059	0.0007	0.0000
Pantropical spotted dolphin	438,064	0.0429	0.0000
Striped dolphin	570,038	0.0792	0.0000
Rough-toothed dolphin	145,729	0.1109	0.0000
Fraser's dolphin	220,789	0.0411	0.0000
Pacific white-sided dolphin	931,000	0.0176	0.0000

Table 11. Estimates of the percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 3, West Philippine Sea, fall season; ESA-listed species highlighted.

OPAREA 3—West Philippine Sea			
Marine Mammal Species	**Number Animals in Stock**	**% Stock Affected <180 dB**	**% Stock Affected (with mitigation) ≥180 dB**
Fin whale	9,250	0.0492	0.0000
Bryde's whale	20,501	0.0653	0.0000
Common minke whale	25,049	0.1880	0.0000
Humpback whale (Winter only)	1,107	< 0.0001	0.0000
Sperm whale	102,112	0.0105	0.0000
Kogia spp.	350,553	0.0099	0.0000
Cuvier's beaked whale	90,725	0.0042	0.0000
Blainville's beaked whale	8,032	0.0797	0.0000
Gingko-toothed beaked whale	22,799	0.0281	0.0000
False killer whale (pelagic)	16,668	0.2610	0.0000
Pygmy killer whale	30,214	0.1043	0.0000
Melon-headed whale	36,770	0.0490	0.0000
Short-finned pilot whale	53,608	0.1348	0.0000
Risso's dolphin	83,289	0.2284	0.0000
Common dolphin	3,286,163	0.0325	0.0000
Bottlenose dolphin[15]	168,791	0.0927	0.0000
Spinner dolphin	1,015,059	0.0004	0.0000
Pantropical spotted dolphin	438,064	0.0230	0.0000
Striped dolphin	570,038	0.0212	0.0000
Rough-toothed dolphin	145,729	0.0769	0.0000
Fraser's dolphin	220,789	0.0284	0.0000
Pacific white-sided dolphin	931,000	0.0211	0.0000

Table 12. Estimates of the percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 4, Offshore Guam, summer and fall seasons; ESA-listed species highlighted.

OPAREA 4—Offshore Guam					
		Summer	Summer	Fall	Fall
Marine Mammal Species	Number Animals in Stock	% Stock Affected <180 dB	% Stock Affected (w/ mitigation) ≥180 dB	% Stock Affected <180 dB	% Stock Affected (w/ mitigation) ≥180 dB
Blue whale	2,842	0.0377	0.0000	0.0338	0.0000
Fin whale	9,250	0.0376	0.0000	0.0354	0.0000
Sei whale	8,600	0.0331	0.0000	0.0330	0.0000
Bryde's whale	20,501	0.0183	0.0000	0.0197	0.0000
Common minke whale	25,049	0.0110	0.0000	0.0104	0.0000
Humpback whale (October to May)	10,103	<0.0001	0.0000	<0.0001	0.0000
Sperm whale	102,112	0.0105	0.0000	0.0104	0.0000
Kogia spp.	350,553	0.0373	0.0000	0.0315	0.0000
Cuvier's beaked whale	90,725	0.0690	0.0000	0.0679	0.0000
Longman's beaked whale	1,007	0.4112	0.0000	0.4043	0.0000
Blainville's beaked whale	8,032	0.1471	0.0000	0.1446	0.0000
Ginkgo-toothed beaked whale	22,799	0.0222	0.0000	0.0218	0.0000
Killer whale	349	0.4894	0.0000	0.4372	0.0000
False killer whale (pelagic)	16,668	0.0699	0.0000	0.0440	0.0000
Pygmy killer whale	30,214	0.0049	0.0000	0.0031	0.0000
Melon-headed whale	36,770	0.1222	0.0000	0.0769	0.0000
Short-finned pilot whale	53,608	0.0350	0.0000	0.0205	0.0000
Risso's dolphin	83,289	0.0141	0.0000	0.0125	0.0000
Common dolphin	3,286,163	0.0007	0.0000	0.0006	0.0000
Bottlenose dolphin[15]	168,791	0.0013	0.0000	0.0009	0.0000
Spinner dolphin	1,015,059	0.0027	0.0000	0.0025	0.0000
Pantropical spotted dolphin	438,064	0.0444	0.0000	0.0417	0.0000
Striped dolphin	570,038	0.0093	0.0000	0.0087	0.0000
Rough-toothed dolphin	145729	0.0022	0.0000	0.0021	0.0000
Fraser's dolphin	10,226	0.411	0.0000	0.3780	0.0000

Table 13. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 5, Sea of Japan, fall season; ESA-listed species highlighted.

OPAREA 5—SEA OF JAPAN			
MARINE MAMMAL SPECIES	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED <180 DB	% STOCK AFFECTED (WITH MITIGATION) ≥180 DB
Fin whale	9,250	0.2345	0.0000
Bryde's whale	20,501	0.0104	0.0000
Common minke whale	25,049	0.0291	0.0000
Common minke whale—J Stock	893	0.3261	0.0000
North Pacific right whale (Spring/Fall/Winter)	922	0.0255	0.0000
Gray whale	121	0.0011	0.0000
Sperm whale	102,112	0.0206	0.0000
Stejneger's beaked whale	8,000	0.5023	0.0000
Baird's beaked Whale	8,000	0.1076	0.0000
Cuvier's beaked Whale	90,725	0.1360	0.0000
Gingko-toothed beaked whale	22,799	0.0629	0.0000
False killer whale (pelagic)	9,777	0.8202	0.0000
Melon-headed whale	36,770	0.0008	0.0000
Short-finned pilot whale	53,608	0.0303	0.0000
Risso's dolphin	83,289	0.2121	0.0000
Common dolphin	3,286,163	0.0529	0.0000
Bottlenose dolphin[15]	105,138	0.0134	0.0000
Spinner dolphin	1,015,059	< 0.0001	0.0000
Pantropical spotted dolphin	219,032	0.0632	0.0000
Pacific white-sided dolphin	931,000	0.0040	0.0000
Dall's porpoise	76,720	0.9218	0.0000

Table 14. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 6, East China Sea, summer season; ESA-listed species highlighted.

OPAREA 6—East China Sea			
Marine Mammal Species	**Number Animals in Stock**	**% Stock Affected <180 dB**	**% Stock Affected (with mitigation) ≥180 dB**
Fin whale	500	0.6200	0.0000
Bryde's whale	20,501	0.0357	0.0000
Common minke whale	25,049	0.2284	0.0000
Common minke whale—J Stock	893	2.6204	0.0000
North Pacific right whale (Winter)	922	< 0.0001	0.0000
Gray whale (Winter only)	121	< 0.0001	0.0000
Sperm whale	102,112	0.0092	0.0000
Kogia spp.	350,553	0.0056	0.0000
Cuvier's beaked whale	90,725	0.0719	0.0000
Blainville's beaked	8,032	0.1530	0.0000
Ginkgo-toothed beaked whale	22,799	0.0230	0.0000
False killer whale (pelagic)	9,777	0.1703	0.0000
Pygmy killer whale	30,214	0.0070	0.0000
Melon-headed whale	36,770	0.1746	0.0000
Short-finned pilot whale	53,608	0.0498	0.0000
Risso's dolphin	83,289	0.1833	0.0000
Common dolphin	3,286,163	0.0202	0.0000
Bottlenose dolphin[15]	105,138	0.0967	0.0000
Spinner dolphin	1,015,059	0.0036	0.0000
Pantropical spotted dolphin	219,032	0.0728	0.0000
Striped dolphin	570,038	0.0334	0.0000
Rough-toothed dolphin	145,729	0.0518	0.0000
Fraser's dolphin	220,789	0.0252	0.0000
Pacific white-sided dolphin	931,000	0.0041	0.0000

Table 15. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 7, South China Sea, fall season; ESA-listed species highlighted.

OPAREA 7—SOUTH CHINA SEA			
MARINE MAMMAL SPECIES	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED <180 dB	% STOCK AFFECTED (WITH MITIGATION) ≥180 dB
Fin whale	9,250	0.0352	0.0000
Bryde's whale	20,501	0.0416	0.0000
Common minke whale	25,049	0.1713	0.0000
North Pacific right whale (Winter)	922	<0.0001	<0.0001
Gray whale (Winter only)	121	<0.0001	0.0000
Sperm whale	102,112	0.0125	0.0000
Kogia spp.	350,553	0.0087	0.0000
Cuvier's beaked whale	90,725	0.0042	0.0000
Blainville's beaked whale	8,032	0.0782	0.0000
Gingko-toothed beaked whale	22,799	0.0276	0.0000
False killer whale (pelagic)	9,777	0.1873	0.0000
Pygmy killer whale	30,214	0.0076	0.0000
Melon-headed whale	36,770	0.1921	0.0000
Short-finned pilot whale	53,608	0.0415	0.0000
Risso's dolphin	83,289	0.2074	0.0000
Common dolphin	3,286,163	0.0210	0.0000
Bottlenose dolphin[15]	105,138	0.0796	0.0000
Spinner dolphin	1,015,059	0.3186	0.0000
Pantropical spotted dolphin	219,032	0.0646	0.0000
Striped dolphin	570,038	0.0296	0.0000
Rough-toothed dolphin	145,729	0.0467	0.0000
Fraser's dolphin	220,789	0.0257	0.0000

Table 16. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 8, northwest Pacific Ocean (from 25ºN to 40ºN), summer season; ESA-listed species highlighted.

OPAREA 8—NW PACIFIC (25ºN TO 40ºN)			
MARINE MAMMAL SPECIES	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED <180 dB	% STOCK AFFECTED (WITH MITIGATION) ≥180 dB
Blue whale	9,250	0.1064	0.0000
Fin whale	9,250	0.0532	0.0000
Sei whale	37,000	0.0400	0.0000
Bryde's whale	20,501	0.1020	0.0000
Common minke whale	25,049	0.0465	0.0000
Sperm whale	102,112	0.0054	0.0000
Kogia spp.	350,553	0.0587	0.0000
Baird's beaked whale	8,000	0.0283	0.0000
Cuvier's beaked whale	90,725	0.0423	0.0000
Mesoplodon spp	22,799	0.0711	0.0000
False killer whale (pelagic)	16,668	0.6998	0.0000
Pygmy killer whale	30,214	0.0150	0.0000
Melon-headed whale	36,770	0.1057	0.0000
Short-finned pilot whale	53,608	0.0014	0.0000
Risso's dolphin	83,289	0.0418	0.0000
Common dolphin	3,286,163	0.1140	0.0000
Bottlenose dolphin	168,791	0.0086	0.0000
Spinner dolphin	1,015,059	< 0.0001	0.0000
Pantropical spotted dolphin	438,064	0.0696	0.0000
Striped dolphin	570,038	0.1477	0.0000
Rough-toothed dolphin	145,729	0.0076	0.0000
Pacific white-sided dolphin	67,769	0.1544	0.0000
Hawaiian monk seal	1,129		

Table 17. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 9, northwest Pacific Ocean, summer season; ESA-listed species highlighted.

OPAREA 9—NW PACIFIC (10°N TO 25°N)			
MARINE MAMMAL SPECIES	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED <180 DB	% STOCK AFFECTED (WITH MITIGATION) ≥180 DB
Bryde's whale	20,501	0.0309	0.0000
Sperm whale	102,112	0.0034	0.0000
Kogia spp.	350,553	0.0044	0.0000
Cuvier's beaked whale	90,725	0.0197	0.0000
False killer whale (pelagic)	16,668	0.1965	0.0000
Melon-headed whale	36,770	0.0509	0.0000
Short-finned pilot whale	53,608	0.0373	0.0000
Risso's dolphin	83,289	0.0478	0.0000
Common dolphin	3,286,163	0.0475	0.0000
Bottlenose dolphin[15]	168,791	0.0074	0.0000
Spinner dolphin	1,015,059	0.0054	0.0000
Pantropical spotted dolphin	438,064	0.0908	0.0000
Striped dolphin	570,038	0.0340	0.0000
Rough-toothed dolphin	145,729	0.0027	0.0000

Table 18. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 10, Hawaii North, summer season; ESA-listed species highlighted.

OPAREA 10—Hawaii North (25°N, 158° W)			
Marine Mammal Species	**Number Animals in Stock**	**% Stock Affected <180 dB**	**% Stock Affected (with mitigation) ≥180 dB**
Blue whale	1,548	0.2295	0.0000
Fin whale	2,099	0.9338	0.0000
Bryde's whale	469	1.1855	0.0000
Common minke whale	25,000	0.0128	0.0000
Humpback whale (Summer)	10,103	< 0.0001	0.0000
Sperm whale	6,919	0.5258	0.0000
Kogia spp.	24,657	1.0271	0.0000
Cuvier's beaked whale	15,242	0.6698	0.0000
Longman's beaked whale	1,007	0.6530	0.0000
Blainville's beaked	2,872	0.6697	0.0000
Killer whale	349	0.7851	0.0000
False killer whale (pelagic)	484	0.8760	0.0000
Pygmy killer whale	956	0.8870	0.0000
Melon-headed whale	2,950	0.8624	0.0000
Short-finned pilot whale	8,870	0.3718	0.0000
Risso's dolphin	2,372	0.9106	0.0000
Bottlenose dolphin	3,215	0.5087	0.0000
Spinner dolphin	3,351	0.2347	0.0000
Pantropical spotted dolphin	8,978	0.2340	0.0000
Striped dolphin	13,143	0.2341	0.0000
Rough-toothed dolphin	8,709	0.9375	0.0000
Fraser's dolphin	10,226	0.7590	0.0000
Hawaiian monk seal	1,129	0.1435	0.0000

Table 19. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 11, Hawaii South, spring and fall seasons; ESA-listed species highlighted.

OPAREA 11—HAWAII SOUTH (19.5°N 158.5°W)			
MARINE MAMMAL SPECIES	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED <180 DB	% STOCK AFFECTED (WITH MITIGATION) ≥180 DB
Blue whale	1,548	0.1288	0.0000
Fin whale	2,099	0.4369	0.0000
Bryde's whale	469	0.5544	0.0000
Common minke whale	25,000	0.0078	0.0000
Humpback whale (not summer)	10,103	0.0003	0.0000
Sperm whale	6,919	0.3391	0.0000
Kogia spp.	24,657	0.5217	0.0000
Cuvier's beaked whale	15,242	0.3985	0.0000
Longman's beaked whale	1,007	0.3885	0.0000
Blainville's beaked	2,872	0.3984	0.0000
Killer whale	349	0.3811	0.0000
False killer whale (pelagic)	484	0.4628	0.0000
Pygmy killer whale	956	0.4686	0.0000
Melon-headed whale	2,950	0.4556	0.0000
Short-finned pilot whale	8,870	0.3527	0.0000
Risso's dolphin	2,372	0.4764	0.0000
Bottlenose dolphin	3,215	0.3514	0.0000
Spinner dolphin	3,351	0.2935	0.0000
Pantropical spotted dolphin	8,978	0.2927	0.0000
Striped dolphin	13,143	0.2928	0.0000
Rough-toothed dolphin	8,709	0.4932	0.0000
Fraser's dolphin	10,226	0.4037	0.0000
Hawaiian monk seal	1,129	0.1010	0.0000

Table 20. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 12, Offshore Southern California, spring season; ESA-listed species highlighted.

OPAREA 12—Offshore Southern California			
MARINE MAMMAL SPECIES	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED <180 dB	% STOCK AFFECTED (WITH MITIGATION) ≥180 dB
Blue whale	2,842	0.8374	0.0000
Fin whale	2,099	2.2178	0.0000
Sei whale	98	1.9876	0.0000
Bryde's whale	13,000	0.0013	0.0000
Common minke whale	823	1.2685	0.0000
Humpback whale	942	1.0485	0.0000
Gray whale	18,813	0.0352	0.0000
Sperm whale	1,934	1.9354	0.0000
Stejneger's beaked whale	1,177	1.9427	0.0000
Baird's beaked whale	1,005	1.9439	0.0000
Cuvier's beaked whale	4,342	1.9531	0.0000
Longman's beaked whale	1,177	1.9427	0.0000
Blainville's beaked whale	1,177	1.9427	0.0000
Ginkgo-toothed beaked whale	1,177	1.9427	0.0000
Hubb's beaked whale	1,177	1.9427	0.0000
Perrin's beaked whale	1,177	1.9427	0.0000
Pygmy beaked whale	1,177	1.9427	0.0000
Killer whale	810	1.9898	0.0000
Pygmy sperm whale	1,237	2.5818	0.0000
Short-finned pilot whale	350	1.5433	0.0000
Risso's dolphin	11,910	2.3572	0.0000
Long-beaked common dolphin	21,902	1.8887	0.0000
Short-beaked common dolphin	352,069	1.8891	0.0000
Bottlenose dolphin	2,026	1.4497	0.0000
Striped dolphin	18,976	1.0087	0.0000
Pacific white-sided dolphin	23,817	1.0370	0.0000
Northern right whale dolphin	11,097	2.4777	0.0000
Dall's porpoise	85,955	0.9666	0.0000
Guadalupe fur seal	7,408	0.7172	0.0000
Northern fur seal	9,424	<0.0001	0.0000
California sea lion (on shelf)	238,000	0.9507	0.0000
California sea lion (offshore)	238,000	<0.0001	0.0000
Northern elephant seal (on shelf)	124,000	0.0191	0.0000
Northern elephant seal (offshore)	124,000	<0.0001	<0.0001
Harbor seal	34,233	0.2559	0.0000

Table 21. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 13, Western Atlantic/Jacksonville OPAREA, winter season; ESA-listed species highlighted.

OPAREA 13—Western Atlantic, Jacksonville OPAREA (off Florida)			
Marine Mammal Species	Number Animals in Stock	% Stock Affected <180 dB	% Stock Affected (with mitigation) ≥180 dB
North Atlantic right whale (on shelf)	438	0.1217	0.0000
Humpback whale	11,570	0.0663	0.0000
Sperm whale (on shelf)	4,804	< 0.0001	0.0000
Sperm whale (off shelf)	4,804	0.1691	0.0000
Short-finned pilot whale (on shelf)	31,139	0.0001	0.0000
Short-finned pilot whale (off shelf)	31,139	2.2997	0.0000
Pygmy sperm whale	580	4.4579	0.0000
Dwarf sperm whale	580	4.4579	0.0000
Beaked whales (on shelf)	3,513	< 0.0001	0.0000
Cuvier's beaked whale (off shelf)	3,513	0.3642	0.0000
Blainville's beaked whale (off shelf)	3,513	0.3642	0.0000
Gervais' beaked whale (off shelf)	3,513	0.3642	0.0000
True's beaked whale (off shelf)	3,513	0.3642	0.0000
Sowerby's beaked whale (off shelf)	3,513	0.3642	0.0000
Risso's dolphin (on shelf)	20,479	0.0054	0.0000
Risso's dolphin (off shelf)	20,479	1.9744	0.0000
Common dolphin	120,743	0.0003	0.0000
Bottlenose dolphin (on shelf)	81,588	0.1150	0.0000
Bottlenose dolphin (off shelf)	81,588	2.8506	0.0000
Pantropical spotted dolphin	12,747	2.8452	0.0000
Striped dolphin	94,462	0.0006	0.0000
Rough-toothed dolphin	274	2.5226	0.0000
Clymene dolphin	6,086	2.8470	0.0000
Atlantic spotted dolphin (on shelf)	50,978	0.4089	0.0000
Atlantic spotted dolphin (off shelf)	50,978	0.1311	0.0000

Table 22. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 14, Eastern North Atlantic, summer season; ESA-listed species highlighted.

OPAREA 14—EASTERN NORTH ATLANTIC (NW APPROACHES)			
MARINE MAMMAL SPECIES	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED <180 DB	% STOCK AFFECTED (WITH MITIGATION) ≥180 DB
Blue whale	100	0.7726	0.0000
Fin whale	10,369	3.4018	0.0000
Sei whale	14,152	9.2473	0.0000
Common minke whale	107,205	0.6518	0.0000
Humpback whale	4,695	1.1710	0.0000
Sperm whale	6,375	2.3498	0.0000
Pygmy sperm whale	580	1.3386	0.0000
Dwarf sperm whale	580	1.3386	0.0000
Cuvier's beaked whale	3,513	1.3685	0.0000
Blainville's beaked whale	3,513	1.3685	0.0000
Sowerby's beaked whale	3,513	1.3685	0.0000
North Atlantic bottlenose whale	5,827	0.1654	0.0000
Killer whale	6,618	0.1607	0.0000
False killer whale (pelagic)	484	1.2615	0.0000
Long-finned pilot whale	778,000	0.0857	0.0000
Risso's dolphin	20,479	2.1137	0.0000
Common dolphin	273,150	9.1833	0.0000
Bottlenose dolphin	81,588	1.0419	0.0000
Striped dolphin	94,462	4.8839	0.0000
Atlantic white-sided dolphin	11,760	1.4759	0.0000
White-beaked dolphin	11,760	1.4759	0.0000
Harbor porpoise	341,366	1.4294	0.0000
Harbor seal	23,500	3.2031	0.0000
Gray seal	113,300	3.7559	0.0000

Table 23. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA potential sonar OPAREA 15, Mediterranean Sea/Ligurian Sea, summer season; ESA-listed species highlighted.

OPAREA 15—Mediterranean Sea, Ligurian Sea			
Marine Mammal Species	**Number Animals in Stock**	**% Stock Affected <180 dB**	**% Stock Affected (with mitigation) ≥180 dB**
Fin whale	3,583	7.0332	0.0000
Sperm whale	6,375	1.7525	0.0000
Cuvier's beaked whale	3,513	1.0139	0.0000
Long-finned pilot whale	778,000	0.0754	0.0000
Risso's dolphin	5,320	6.7105	0.0000
Common dolphin	19,428	4.4472	0.0000
Bottlenose dolphin	23,304	10.3802	0.0000
Striped dolphin	117,880	8.8565	0.0000

Table 24. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 16, Arabian Sea, summer season; ESA-listed species highlighted.

OPAREA 16—Arabian Sea			
Marine Mammal Species	**Number Animals in Stock**	**% Stock Affected <180 dB**	**% Stock Affected (with mitigation) ≥180 dB**
Bryde's whale	9,176	0.0134	0.0000
Humpback whale	200	1.5275	0.0000
Sperm whale	24,446	0.4530	0.0000
Dwarf sperm whale	10,541	4.1267	0.0000
Cuvier's beaked whale	27,272	0.0073	0.0000
Longman's beaked whale	16,887	0.1880	0.0000
Blainville's beaked whale	16,887	0.1880	0.0000
Ginkgo-toothed beaked whale	16,887	0.1880	0.0000
False killer whale (pelagic)	144,188	0.0056	0.0000
Pygmy killer whale	22,029	0.3187	0.0000
Melon-headed whale	64,600	2.7627	0.0000
Short-finned pilot whale	268,751	0.0078	0.0000
Risso's dolphin	452,125	0.0357	0.0000
Common dolphin	1,819,882	0.0373	0.0000
Bottlenose dolphin[15]	785,585	0.0393	0.0000
Spinner dolphin	634,108	0.0066	0.0000
Pantropical spotted dolphin	736,575	0.0072	0.0000
Striped dolphin	674,578	0.0437	0.0000
Rough-toothed dolphin	156,690	0.0663	0.0000

Table 25. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 17, Andaman Sea, summer season; ESA-listed species highlighted.

OPAREA 17—Andaman Sea			
Marine Mammal Species	**Number Animals in Stock**	**% Stock Affected <180 dB**	**% Stock Affected (with mitigation) ≥180 dB**
Bryde's whale	9,176	0.0094	0.0000
Sperm whale	24,446	0.5369	0.0000
Dwarf sperm whale	10,541	1.5682	0.0000
Cuvier's beaked whale	16,867	0.1214	0.0000
Longman's beaked whale	16,867	0.1214	0.0000
Blainville's beaked whale	16,867	0.1214	0.0000
Ginkgo-toothed beaked whale	16,867	0.1214	0.0000
Killer whale	12,593	0.0079	0.0000
False killer whale (pelagic)	144,188	0.0017	0.0000
Pygmy killer whale	22,029	0.0970	0.0000
Melon-headed whale	64,600	0.8411	0.0000
Short-finned pilot whale	268,751	0.0079	0.0000
Risso's dolphin	452,125	0.0337	0.0000
Common dolphin	1,819,882	0.0130	0.0000
Bottlenose dolphin[15]	785,585	0.0122	0.0000
Spinner dolphin	634,108	0.0095	0.0000
Pantropical spotted dolphin	736,575	0.0104	0.0000
Striped dolphin	674,578	0.0632	0.0000
Rough-toothed dolphin	156,690	0.0724	0.0000

Table 26. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 18, Panama Canal, winter season; ESA-listed species highlighted.

OPAREA 18—Panama Canal (Western Approaches)			
Marine Mammal Species	**Number Animals in Stock**	**% Stock Affected <180 dB**	**% Stock Affected (with mitigation) ≥180 dB**
Blue whale	2,842	0.0287	0.0000
Bryde's whale	13,000	0.0197	0.0000
Humpback whale	1,391	0.0034	0.0000
Sperm whale	22,700	0.1604	0.0000
Dwarf sperm whale	11,200	1.711	0.0000
Cuvier's beaked whale	20,000	0.1204	0.0000
Longman's beaked whale	25,300	0.0112	0.0000
Blainville's beaked whale	25,300	0.0502	0.0000
Ginkgo-toothed beaked whale	25,300	0.0617	0.0000
Pygmy beaked whale	25,300	0.0617	0.0000
Killer whale	8,500	0.0116	0.0000
False killer whale (pelagic)	39,800	0.0082	0.0000
Pygmy killer whale	38,900	0.0316	0.0000
Melon-headed whale	45,400	0.3324	0.0000
Short-finned pilot whale	160,200	0.0288	0.0000
Risso's dolphin	110,457	0.1724	0.0000
Common dolphin	3,127,203	0.0153	0.0000
Bottlenose dolphin	335,834	0.0363	0.0000
Spinner dolphin	450,000	0.0082	0.0000
Pantropical spotted dolphin	640,000	0.0549	0.0000
Striped dolphin	964,362	0.0653	0.0000
Rough-toothed dolphin	107,633	0.1744	0.0000
Fraser's dolphin	289,300	0.0030	0.0000

Table 27. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 19, Northeast Australia Coast, spring season; ESA-listed species highlighted.

OPAREA 19—NORTHEAST AUSTRALIA COAST			
MARINE MAMMAL SPECIES	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED <180 DB	% STOCK AFFECTED (WITH MITIGATION) ≥180 DB
Blue whale	9,250	0.0311	0.0000
Fin whale	9,250	0.0392	0.0000
Bryde's whale	22,000	0.0389	0.0000
Common minke whale	25,000	0.2466	0.0000
Humpback whale inshore (<200 m)	3,500	7.1143	0.0000
Humpback whale offshore (>200 m)	3,500	0.1990	0.0000
Sperm whale	102,112	0.0367	0.0000
Pygmy sperm whale	350,553	0.0187	0.0000
Dwarf sperm whale	350,553	0.0187	0.0000
Cuvier's beaked whale	3,286,163	0.0265	0.0000
Longman's beaked whale	22,799	0.0375	0.0000
Blainville's beaked whale	8,032	0.1065	0.0000
Ginkgo-toothed beaked whale	22,799	0.0375	0.0000
Arnoux’s beaked whale	90,725	0.1018	0.0000
Southern bottlenose whale	22,799	0.0375	0.0000
Killer whale	12,256	0.0594	0.0000
Pygmy killer whale	30,214	0.1768	0.0000
False killer whale (pelagic)	16,668	0.4427	0.0000
Melon-headed whale	36,770	0.0830	0.0000
Short-finned pilot whale	53,608	0.5580	0.0000
Long-finned pilot whale	53,608	0.5580	0.0000
Risso's dolphin	220,789	0.0280	0.0000
Common dolphin	83,289	0.2586	0.0000
Spinner dolphin	145,729	0.0837	0.0000
Pantropical spotted dolphin	570,038	0.0738	0.0000
Striped dolphin	1,015,059	0.0006	0.0000
Rough-toothed dolphin	168,791	0.1438	0.0000
Fraser's dolphin	12,626	0.0228	0.0000
Dusky dolphin	438,064	0.0400	0.0000

7 IMPACTS TO MARINE MAMMAL SPECIES OR STOCKS

Requirement 7: Anticipated impact of the activity upon the species or stocks.

Level A harassment can result from auditoriallly or non-auditorially induced injury. Auditory injury or permanent threshold shift (PTS) has been defined by the SURTASS LFA sonar program as the deterioration of hearing due to prolonged or repeated exposure to sounds that accelerate the normal process of gradual hearing loss (Kryter, 1985) and the permanent hearing damage from brief exposure to extremely high sound levels (Richardson et al., 1995). PTS results in a permanent elevation in hearing threshold—an unrecoverable reduction in hearing sensitivity (Southall et al., 2007), which is thus, considered to be an injury. In the first and second MMPA Rules for the employment of SURTASS LFA sonar (NOAA, 2002 and 2007), NMFS adopted the standard that a 20-dB threshold shift defines the onset of permanent threshold shift (PTS) (i.e., a shift of 20 dB in hearing threshold) or injury (Level A harassment). Southall et al. (2007) proposed injury criteria for individual LF/MF/HF marine mammals exposed to non-pulsed sound types, which included discrete acoustic exposures from SURTASS LFA sonar. The proposed injury criteria for cetaceans and pinnipeds in water are SELs of 215 dB re 1 μPa^2-sec RL and 203 dB re 1 μPa^2-sec RL, respectively. A 18-dB adjustment must be made for the longer LFA signal (nominally 60 seconds) resulting in injury criteria for SURTASS LFA sonar for LF/MF/HF cetaceans of a SEL of 197 dB re 1 μPa^2-sec RL and for pinnipeds in water of a SEL of 185 dB RL. The injury criterion for all marine mammals used by the DoN in its risk/impact assessments of SURTASS LFA sonar was an SPL of 180 dB RL, which is noticeably lower and, therefore, more conservative, than the injury criteria proposed by Southall et al. (2007).

This conservative injury criterion was used in analysis and modeling of real-world potential operating sites for SURTASS LFA sonar to assess the potential for Level A harassment or auditory injury to marine mammals resulting from use of the sonar. Although it is impossible for the DoN to accurately predict where LFA surveillance ships will be operated in the future, 50 real-world marine environments suitable as potential operating areas for SURTASS LFA sonar were selected for analysis and modeling to predict pre-operational Level A harassment or injury values. The comprehensive modeling and analysis conducted since the beginning of the SURTASS LFA sonar program has resulted in no (0%) estimated risk of Level A harassment for any marine mammal species or stocks, given that the full suite of mitigation measures were employed (see Tables 9 through 27). Similarly, post-operational analyses conducted for the annual reporting requirements for operational years 2007 through 2009 (first through third years of existing LOA) of the SURTASS LFA sonar program have also shown that no (0%) Level A harassment (Tables 6 to 8) was estimated for any marine mammal species or stock based on actual operations and no species or stocks were affected in any of the three years by transmissions >180 dB, with mitigation measures implemented.

Non-auditory injury or Level A harassment may be possible as the result of direct acoustic impact on tissue, indirect acoustic impact on tissue surrounding a structure, and acoustically mediated bubble growth within tissues from supersaturated dissolved nitrogen gas. Physical effects, such as direct acoustic trauma or acoustically enhanced bubble growth, require relatively intense received energy that would only occur at short distances from high-powered sonar sources (Nowacek et al., 2007; Zimmer and Tyack, 2007). While resonance can occur in marine animals, this resonance does not necessarily cause injury, and any such injury is not expected to occur below a received sound pressure level (RL) of 180 dB re 1 μPa (rms). Damage to the lungs and large sinus cavities of cetaceans from air space resonance is not regarded as a likely significant non-auditory injury because resonance frequencies of marine mammal lungs are below that of the LFA signal (Finneran, 2003).

An additional type of non-auditory injury, nitrogen gas bubble formation that results in a form of decompression sickness, is an area of much research and theorization recently. Gas bubble lesions were originated noted in stranded marine mammals, some of which stranded after acoustic naval exercises. An early hypothesis for gas bubble formation in beaked whale strandings is that the whales potentially have strong avoidance responses, such as swiftly diving to depth, to escape sounds similar to their principal predator, the killer whale (Cox et al., 2006; Southall et al., 2007; Zimmer and Tyack, 2007; Baird et al., 2008; Hooker et al., 2009). Subsequent research has shown, however, that gas bubble lesions can form with repeated lengthy dives with short to medium surface durations (Zimmer and Tyack, 2007; Fahlman et al., 2009; Moore et al., 2009). Despite the increased scientific research and discussion on gas bubble formation, scientists agree that there is insufficient evidence to support gas bubble formation as the likely cause for certain types of acoustic exposures and marine mammal stranding events (Southall et al., 2007). Regardless, since LFA sonar signals are lower in frequency (<500 Hz) and not similar in characteristic to the vocalizations of marine mammal predators, there is no evidence that SURTASS LFA sonar has or would cause behavioral reactions such as avoidance responses in beaked whales that may have led ultimately to the formation of gas bubble lesions and potentially stranding. Thus, SURTASS LFA sonar transmissions are not reasonably expected to cause injury such as gas bubble formation or beaked whale strandings.

Indeed, to date, no strandings of marine mammals have been associated with the employment of SURTASS LFA sonar since its use began the early 2000s. Operation of SURTASS LFA sonar, with the comprehensive suite of mitigation measures implemented, have produced no known lethal removal impacts (i.e., Level A takes) to marine mammal stocks or species as reported in the DoN Annual Reports from 2003 through 2010. In summary, for the reasons listed above, the Navy has concluded that the likelihood of SURTASS LFA sonar transmissions (with mitigation measures implemented) causing injury or Level A harassment in marine mammals is considered negligible and are not reasonably expected from future deployment and use of LFA sonar. Thus, for this application, the only impacts anticipated from SURTASS LFA sonar transmission are short-term Level B behavioral harassment that will affect only a small percentage of the marine mammal stocks (~5% estimated for any one stock based on post-operation data and no more than 10% of any one stock for predicted, modeled operational sites, for <180 dB transmissions).

Based on the results of the analyses conducted for SURTASS LFA sonar operations and more than seven years of documented operational results that are summarized in this application and presented in the NEPA documentation, operation of SURTASS LFA sonar, when employed in accordance with the mitigation measures (geographic restrictions and monitoring/reporting), support a negative impact determination. In summary:

- Potential effects on marine mammals are reasonably expected to be limited to Level B harassment. The Navy does not estimate the Level B effects to impact rates of recruitment or survival on the associated marine mammal species and stocks. Thus, effects on recruitment or survival are expected to be negligible.
    - Level B harassment of marine mammals will not occur in ocean areas that are biologically important to marine mammals (e.g., foraging, reproductive areas, rookeries, ESA critical habitat) or that are where small, localized populations occur. Twenty-one areas of global importance to marine mammals have been restricted from LFA sonar use, so no harassment of marine mammals will occur in these essential marine habitats.
- Potential for non-injurious effects (TTS, masking, modification of biological important behavior) is minimal to negligible for marine mammals.
- Based on the Navy‘s impact analysis results, no mortality nor injury (i.e., Level A) of marine mammals is predicted to occur as a result of LFA sonar operations, and the potential of the sonar to cause strandings of marine mammals is considered negligible.

- The employment of SURTASS LFA sonar will entail the addition of sound energy to the oceanic ambient noise environment, which in conjunction with the sound produced by other anthropogenic sources may increase the overall oceanic ambient noise level. Increases in ambient noise levels have the potential to affect marine animals by causing masking. However, broadband, continuous low-frequency ambient noise is more likely to affect marine mammals than narrowband, low duty cycle SURTASS LFA sonar. Moreover, the bandwidth of any SURTASS LFA sonar transmitted signal is limited (approximately 30 Hz), the average maximum pulse length is 60 seconds, signals do not remain at a single frequency for more than 10 seconds, and the system is off nominally 90 to 92.5% of the time during an at-sea operation. However, with the nominal duty cycle of 7.5 to 10%, masking by LFA sonar would only occur over a very small spatial and temporal scale. Also, the number of potential LFA sonar operating in the world's ocean are small, no more than four systems in operation over the next five years. The cumulative effects related to the potential for masking from the potential four SURTASS LFA sonar systems are not a reasonably foreseeable significant adverse impact on marine animals.
- Employment of SURTASS LFA sonar will not impact the habitat of marine mammals nor result in loss or modification of marine habitat.
- Annually, each of the possible four SURTASS LFA sonar vessels will spend no more than 240 days performing active operations with a maximum of 432 hrs of sonar transmission per vessel per year.
- A comprehensive suite of mitigation measures, including three types of monitoring (passive acoustic, active acoustic, and visual) during sonar operations, coastal standoff range (180 dB SPL sound field restricted to 22 km [12 nmi] from shore), and OBIA restrictions (sound field produced by sonar below 180 dB RL, based on SPL modeling), will be implemented to reduce the potential for harassment to marine mammals.

Consideration of negligible impact is required for NMFS to authorize incidental take of marine mammals. By definition, an activity has a "negligible impact" on a species or stock when ''an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival'' (50 CFR 216.103). The Navy has concluded that the incidental taking of marine mammals by the employment of SURTASS LFA sonar in any of the potential worldwide operating areas will have a negligible impact on the affected marine mammal stocks or species of marine mammals.

8 IMPACT ON SUBSISTENCE USE

Requirement 8: Anticipated impact of the activity on the availability of the species or stocks of marine mammals for subsistence uses.

Although SURTASS LFA sonar will not be operated in the vast majority of Arctic waters, the sonar may potentially be operated in the Gulf of Alaska, where subsistence uses of marine mammals occurs. Subsistence uses of marine mammals in the Gulf of Alaska include the harvest of harbor seals and Steller sea lions along coastal and inshore, including bay, areas of the gulf. As many as six Alaskan Native groups subsistence hunt harbor seals in the Gulf of Alaska, although the Dena'ina only occasionally hunt harbor seals, and four Native groups hunt Steller sea lions, with the Southeastern Alaska Native groups only occasionally harvesting Stellers (Wolfe et al., 2009). Subsistence products that are derived from harbor seals and Steller sea lions by these Alaskan Native groups include oil, meat, and skins. Subsistence hunting of harbor seals and Steller sea lions is a specialized activity amongst Alaska Native groups, with only 30% and 3% of the surveyed native households hunting harbor seals and Steller sea lions, respectively (Wolfe et al., 2009).

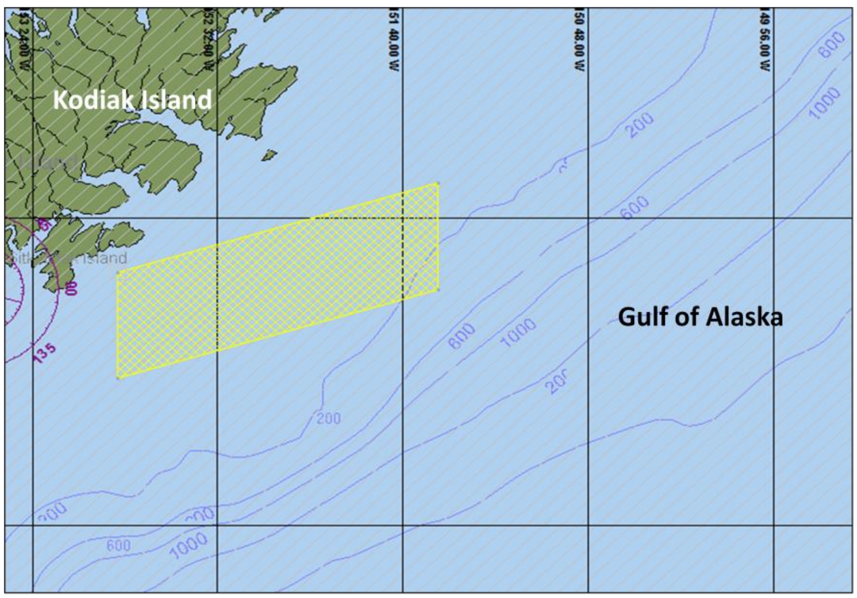
Table 28. Alaskan Native Groups subsistence harvesting harbor seals and Steller sea lions in the Gulf of Alaska (Wolfe et al, 2009).

ALASKAN NATIVE GROUP	ALASKA REGION
Harbor Seals	
Alutiiq	Central Gulf of Alaska
Eyak	Central Gulf of Alaska
Tlingit	Southeastern Alaska
Haida	Southeastern Alaska
Tsimshian	Southeastern Alaska
Dena'ina	Cook Inlet
Steller Sea Lions	
Alutiiq	Kodiak Island, Gulf of Alaska
Tlingit	Southeastern Alaska
Haida	Southeastern Alaska
Tsimshian	Southeastern Alaska

Two stocks of harbor seals have been distinguished for the waters of the Gulf of Alaska, the Gulf of Alaska and Southeast Alaska stocks (Allen and Angliss, 2011). During 2008, 1,274 harbor seals of these two stocks were harvested or struck but lost; this was the second lowest number of animals harvested/struck since 1992 (Wolfe et al., 2009). The largest numbers of harbor seals taken by subsistence hunting in the overall Gulf of Alaska are in the southeastern Alaska region by the Tlingit and Haida tribes, who in 2008 harvested or struck 41% of the total number of harbor seals (Wolfe et al., 2009). Harbor seals were taken in all months of 2008, but harvests peaked in March and November, although the seasonal trends were not as distinguishable as that in the previous years since records have been documented beginning in 1992 (Wolfe et al., 2009). More male than female harbor seals were harvested and more adults than juveniles were taken in 2008 (Wolfe et al., 2009).

The Steller sea lions in the Gulf of Alaska occur in two stocks, the Western or Eastern stocks, although the Western stock also encompasses waters of the Bering Strait and Bering Sea, where SURTASS LFA sonar will not be operated (Allen and Angliss, 2011). In 2008, 63 Steller sea lions were harvested or struck but lost in the waters of the Gulf of Alaska, with sea lions being taken in every month (Wolfe et al., 2009). Peaks in harvest occurred in February through April and again in November, although the seasonal trend is weak due to the reduced number of sea lions harvested in comparison to the early 1990s (Wolfe et al., 2009). Similarly to the harbor seal harvest, more males than female Steller sea lions were taken but more juveniles were taken than adults in the 2008 subsistence harvest.

During the review and comment period for the Draft SEIS for SURTASS LFA sonar employment (DoN, 2011), letters requesting review of the Draft SEIS and comments will have been solicited from the Alaska Native groups (listed above) that currently participate in subsistence use of harbor seals and Steller sea lions in the Gulf of Alaska region. Should SURTASS LFA sonar be operated in the Gulf of Alaska, sonar operation would adhere to established geographic restrictions, which include the coastal standoff range (which dictates that the sound field produced by the sonar must be below 180 dB SPL within 22 km (12 nmi) of any coastline) and exclusion from OBIAs. An OBIA in the Gulf of Alaska has been proposed to encompass the portion of the North Pacific right whale's critical habitat that has been designated in the gulf (Figure 4).



Not to Scale

Figure 4. Marine mammal OBIA in the Gulf of Alaska that encompasses the North Pacific right whale's critical habitat.

Although there are peaks in harvest activity for both species, both harbor seals and Steller sea lions are harvested year-round in the coastal waters of the gulf. While it is impossible to predict the future timing of the possible employment of SURTASS LFA sonar in the Gulf of Alaska, regardless of the time of year the sonar may be employed in the Gulf of Alaska, there should be no overlap in time or space with subsistence hunts due to the geographic restrictions on the sonar use (i.e., coastal standoff range and OBIA restrictions). These restrictions will prevent the sonar from being used or the sound field it generates from reaching the shallow coastal and inshore areas of the Gulf of Alaska where harvest of the two pinniped species occurs. The possible employment of SURTASS LFA sonar in the Gulf of Alaska will not cause abandonment of any harvest/hunting locations, will not displace any subsistence users, nor place physical barriers between marine mammals and the hunters. No mortalities of marine mammals have been associated with the employment of SURTASS LFA sonar and the Navy undertakes a suite of mitigation measures whenever SURTASS LFA sonar is actively transmitting. Therefore, the possible future employment of SURTASS LFA sonar will not lead to unmitigatable adverse impacts on the availability of marine mammal species or stocks for the subsistence uses in the Gulf of Alaska.

9 IMPACT TO MARINE MAMMAL HABITAT

Requirement 9: Anticipated impact of the activity upon the habitat of the marine mammal populations, and the likelihood of restoration of the affected habitat.

9.1 PHYSICAL HABITAT

Use of SURTASS LFA sonar entails the periodic deployment of acoustic transducers and receivers into the water column from ocean-going ships. SURTASS LFA sonar is deployed from ocean surveillance ships that are U.S. Coast Guard-certified for operations and operate in accordance with all applicable federal, international, and U.S. Navy rules and regulations related to environmental compliance, especially for discharge of potentially hazardous materials. In particular, SURTASS LFA sonar ships comply with all requirements of the Clean Water Act (CWA) and Act to Prevent from Ships (APPS). SURTASS LFA vessel movements are not unusual or extraordinary and are part of routine operations of seagoing vessels. Therefore, no discharges of pollutants regulated under the APPS or CWA will result from the operation of the sonar systems nor will unregulated environmental impacts from the operation of the SURTASS LFA sonar vessels occur.

9.2 SOUND IN THE ENVIRONMENT

Deployment and use of the sonar systems results in no physical alterations to the marine environment other than the addition of sound energy to the oceanic ambient noise environment, which may have some effect on marine animals. Anthropogenic sources of ambient noise that are most likely to have contributed to increases in ambient noise levels are commercial shipping, offshore oil and gas exploration and drilling, and naval and other use of sonar (ICES, 2005; MMC, 2007). Hildebrand (2005) concluded that increases in anthropogenic oceanic sound sources most likely to contribute to increased noise in order of importance are: commercial shipping, offshore oil and gas exploration and drilling, and naval and other uses of sonar.

The potential effects that up to four SURTASS LFA sonars may have on the overall oceanic ambient noise level are reviewed in the following contexts:

- Recent reports on ambient sound levels in the world's oceans;
- Operational parameters of the SURTASS LFA sonar system, including proposed mitigation;
- Contribution of SURTASS LFA sonar to oceanic noise levels relative to other human-generated sources of oceanic noise; and
- Cumulative effects from concurrent LFA/MFA sonar operations.

9.2.1 OCEANIC NOISE LEVELS

Ambient noise is the typical or persistent environmental background noise that is present throughout the ocean; it is generated by both natural and anthropogenic sources. The U.S. Marine Mammal Commission, in a recently published document on underwater sound in the marine environment, classifies ambient noise into three broad categories: natural biotic, which can include marine animals, fish, and invertebrates; natural abiotic, such as seismic disturbances; and anthropogenic, which includes noise from shipping vessels and seismic surveying (Bradley and Stern, 2008). Thus, any potential for cumulative effects should be put into the context of recent changes to ambient sound levels in the world's oceans.

Andrew et al. (2002) compared ocean ambient sound from the 1960s with the 1990s for a receiver off the California coast. The data showed an increase in ambient noise of approximately 10 dB SPL in the frequency range of 20 to 80 Hz and 200 and 300 Hz, and about 3 dB SPL at 100 Hz over a 33-year period. A possible explanation for the rise in ambient noise is the increase in shipping noise. More recently, McDonald et al. (2006) compared northeast Pacific Ocean ambient noise levels over the past four decades, from continuous measurements west of San Nicolas Island, California. Ambient noise levels at 30 to 50 Hz were 10 to 12 dB SPL higher in 2003 to 2004 than in 1964 to 1966, suggesting an increase in the rate of average noise of 2.5 to 3 dB SPL per decade. Above 50 Hz, the noise level differences between recording periods gradually diminished to a rise of 1 to 3 dB SPL at 100 to 300 Hz. McDonald et al. (2006) cite commercial shipping as the most plausible explanation for the measured increases.

The number of commercial vessels plying the world's oceans approximately doubled between 1965 and 2003, and the gross tonnage quadrupled, with a corresponding increase in horsepower (McDonald et al., 2006). Clark et al. (2009) demonstrated that acoustic communications space for the highly endangered North Atlantic right whale is seriously compromised by anthropogenic noise from commercial shipping traffic.

In a recent study, Di Iorio and Clark (2009) found that blue whales increase their rate of social calling in the presence of seismic exploration sparkers (plasma sound sources), which presumably represented a compensatory behavior to elevated ambient noise levels from seismic surveys. Southall et al. (2009a) noted that even though naval and geophysical sound sources are currently receiving the greatest attention, other lower-power but more ubiquitous sound sources that add to the ambient noise environment occur in far greater numbers and cover much greater geographical ranges and deployment times.

Recent scientific papers and research have reported concerns about the increase in ocean surface acidity and the effects that this will have on ocean noise. Increased levels of carbon dioxide in the atmosphere are raising the dissolved carbon dioxide contents in the oceans, which produces carbonic acid (Hester et al., 2008; Brewer and Hester, 2009; Doney et al., 2009; Ilyina et al., 2010). Because the transmission loss of low frequency sound will decrease with increasing acidity, ocean background noise levels could increase. Several long term predictive models have been developed (Joseph and Chiu, 2010; Reeder and Chiu, 2010; Udovydchenkov et al., 2010). Over the next 100 years, predicted increases in LF ocean noise from acidification will be less than the present variability (approximately 1 dB) in background noise levels for LF.

9.2.1.1 Effects of Ambient Noise

Oceanic ambient noise levels are increasing due to the global escalation in numbers of anthropogenic sources. There is increasing scientific evidence indicating effects on marine mammals from this escalation. In a study by Parks et al. (2007), evidence was provided of a behavioral change in sound production of the North and South Atlantic right whales, which was correlated with increased underwater ambient noise levels. This indicated that right whales might shift their call frequency to compensate for the increasing band-limitations caused by background noise. Holt et al. (2009) studied the effects of anthropogenic sound exposure on the endangered Southern Resident killer whales in Puget Sound, reporting that these whales increased their call amplitude by 1 dB SPL for every 1 dB SPL increase in background noise (1 to 40 kHz).

9.2.1.2 SURTASS LFA Sonar Combined with Other Human-Generated Sources of Oceanic Noise

Increases in ambient noise levels have the potential to cause masking and decrease the distances that underwater sound can be detected by marine animals. These effects have the potential to cause a long-term decrease in a marine mammal's efficiency at foraging, navigating, or communicating (ICES, 2005). NRC (2003) discussed acoustically-induced stress in marine mammals and stated that sounds resulting from one-time exposure are less likely to have population-level effects than sounds that animals are exposed to repeatedly over extended periods of time. NRC (2005) focused on the concept of allostatic[16] load as an alternative to the acoustically-induced "stress"; this concept considers energy budgets and life-history events and is based on McEwen and Wingfield (2003). and was adapted from the cardiovascular field and was introduced for more broad application in McEwen and Stellar (1993).

There is the potential for cumulative effects from SURTASS LFA transmissions in conjunction with other anthropogenic sources to increase the overall oceanic ambient noise level, including the potential for LFA sound to add to overall ambient levels of anthropogenic noise. Broadband, continuous low-frequency ambient noise is more likely to affect marine mammals than narrowband, low duty cycle SURTASS LFA sonar. Moreover, the bandwidth of any SURTASS LFA sonar transmitted signal is limited (approximately 30 Hz), the average maximum pulse length is 60 seconds, signals do not remain at a single frequency for more than 10 seconds, and during an operation the system is off nominally 90 to 92.5% of the time. Most mysticete vocalizations are in the low frequency band below 1 kHz, and it is generally believed that their frequency band of best hearing is below 1 kHz, where their calls have the greatest energy (Clark, 1990; Edds-Walton, 2000; Ketten, 2000). However, with the nominal duty cycle of 7.5 to 10%, masking by LFA would only occur over a very small spatial and temporal scale. For these reasons, any masking effects from SURTASS LFA sonar are expected to be negligible.

The number of SURTASS LFA sonar systems is not scheduled to increase but will remain at the same level of four potentially operating systems during the next five–year regulation under the MMPA. Therefore, LFA transmissions will not significantly increase anthropogenic oceanic noise in the next five years over that of the previous analyses. The cumulative effects related to the potential for masking from the proposed four SURTASS LFA sonar systems are not a reasonably foreseeable significant adverse impact on marine animals.

9.3 PROTECTED MARINE HABITATS

Many habitats in the marine environment are protected for a variety of reasons but typically, habitats are designated to conserve and manage natural and cultural resources. Protected marine and aquatic habitats have defined boundaries and are typically enabled under some Federal, State, or international legal authority. Habitats are protected for a variety of reasons including intrinsic ecological value; biological importance to specific marine species or taxa, which are often also protected by federal or international agreements; management of fisheries; and cultural or historic significance. Due to their importance as marine mammal habitat, two types of marine habitats protected under U.S. legislation or Presidential EO are considered here. These marine habitats include critical habitat designated under the ESA and marine protected areas (MPAs) designated under the National Marine Sanctuaries Act and EO 13158.

9.3.1 ESA CRITICAL HABITAT

The ESA, and its amendments, require the responsible agencies of the Federal government to designate critical habitat for any species that it lists under the ESA. Critical habitat is defined under the ESA as:

1. the specific areas within the geographic area occupied by a listed threatened or endangered species on which the physical or biological features essential to the conservation of the species are found, and that may require special management consideration or protection; and
2. specific areas outside the geographic area occupied by a listed threatened or endangered species that are essential to the conservation of the species (16 U.S.C. §1532(5)(A), 1978).

16 Allostasis refers to the physiological and behavioral mechanisms used by an organism to support homeostasis (the stability of the physiological systems that maintain life) in the face of normal and relatively predictable life-history events, such as migration, mating, rearing young, and seasonal changes in resource availability; and unpredictable events such as decreases in oceanic productivity and increases in human disturbances; and more permanent handicaps, such as injuries, parasites, and contaminant loads.

Critical habitat designations are not required for foreign species or those species listed under the ESA prior to the 1978 amendments to the ESA that added critical habitat provisions. Under Section 7 of the ESA, all Federal agencies must ensure that any actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of a listed species or destroy or adversely modify its designated critical habitat. Critical habitat designations must be based on the best scientific information available and designated in an open public process and within specific timeframes. Before designating critical habitat, careful consideration must be given to the economic impacts, impacts on national security, and other relevant impacts of specifying any particular area as critical habitat.

Seventy-three marine and anadromous species have been listed as threatened or endangered under the ESA. Of those, critical habitat has only been designated for six ESA-listed marine mammals (Table 29; NMFS, 2011). The NMFS has jurisdiction over the marine and anadromous species listed under ESA and their designated critical habitat. Of the designated critical habitat for marine mammals, the critical habitat of only four of the designated marine mammal species is in the marine environment at a distance sufficient from shore to potentially be affected by SURTASS LFA sonar.

Table 29. ESA-listed marine mammal species for which critical habitat has been designated.

Species	Status Under ESA	Listed Distinct Population Segment (DPS) / Population/Evolutionarily Significant Unit (ESU)	Critical Habitat—Type of Habitat Designated
Beluga whale	Endangered	Cook Inlet	Inshore
Killer whale	Endangered	Southern Resident	Inshore
North Atlantic right whale	Endangered		Marine, nearshore and >12 nmi
North Pacific right whale	Endangered		Marine, nearshore and >12 nmi
Hawaiian monk seal	Endangered		Marine, nearshore <12 nmi
Steller sea lion	Threatened	Eastern	Marine, nearshore and >12 nmi
	Endangered	Western	Marine, nearshore <12 nmi

For this reason, the more extensive OBIA analysis considered these critical habitat areas and designated all but the critical habitat of the Steller sea lion as a marine mammal OBIA for SURTASS LFA sonar. Much of the critical habitat for the Steller sea lion is located in the Bering Sea, where SURTASS LFA sonar will not operate. Although it is possible that the sonar will be operated in the western Gulf of Alaska where the eastern critical habitat for the Steller sea lion is located and some of that habitat lies outside of 22 km (12 nmi) from shore, the water depth in which the habitat is found is sufficiently shallow that it is unlikely that the sonar would ever be operated in the vicinity of that critical habitat. Thus, the likelihood of SURTASS LFA sonar adversely affecting critical habitats is negligible.

9.3.2 Marine Protected Areas

The term “marine protected area” (MPA) is very generalized and is used to describe specific regions of the marine and aquatic environments that have been set aside for protection, usually by individual nations within their territorial waters, although a small number of internationally recognized MPAs exist. Of the estimated 5,000 global MPAs, about 10% are international (WDPA, 2009). The variety of names and uses of MPAs has led to confusion over what the term really means and where MPAs are used. Internationally, a MPA is considered "any area of the intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (Kelleher, 1999). In the U.S., a MPA is defined by EO 13158 as "any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein."

9.3.2.1 U.S. Marine Protected Areas

In the U.S., MPAs have conservation or management purposes, defined boundaries, a permanent protection status, and some legal authority to protect marine or aquatic resources. In practice, U.S. MPAs are defined marine and aquatic geographic areas where natural and/or cultural resources are given greater protection than is given in the surrounding waters. U.S. MPAs span a range of habitats including the open ocean, coastal areas, inter-tidal zones, estuaries, as well as the Great Lakes and vary widely in purpose, legal authority, agencies, management approaches, level of protection, and restrictions on human uses (NMPAC, 2009). Currently, about 100 Federal, state, territory, and tribal agencies manage more than 1,500 marine areas in the U.S. and its territories (NMPAC, 2009a). Two federal agencies primarily manage federally designated MPAs. The Department of Commerce's NOAA manages national marine sanctuaries (NMS), fishery management zones (FMZ), and in partnership with states, national estuarine research reserves (NERR), while the Department of Interior manages the national wildlife refuges (NWRs) and the national park system (NPS), which includes national parks (NPs), national seashores (NSs), and national monuments (NMs).

Over the past century in the U.S., Federal, state, territory, and local legislation; voter initiatives; and regulations have created the plethora of 1,500 MPAs that now exist, each of which was established for a specific purpose. The resulting collection of U.S. MPAs, consisting of reserves, refuges, preserves, sanctuaries, parks, monuments, national seashores, areas of special biological significance, fishery management zones, and critical habitats, is so fragmented, unrelated, and confusing that potential opportunities for broader regional conservation through coordinated planning and management are often missed.

To address this situation and improve the nation's ability to understand and preserve its marine resources, Presidential EO 13158 of 2000 called for an evaluation and inventory of the existing MPAs and development of a national MPA system and national MPA center. The EO called for a national system that protects both natural and cultural marine resources and is based on a strong scientific foundation. The Department of Commerce established the National MPA Center (NMPAC), which has inventoried the existing U.S. MPAs and has developed the criteria for the national MPA system. Although EO 13158 provided the formal definition of a MPA, the NMPAC has developed a classification system that provides definitions and qualifications for the various terms within the EO (NMPAC, 2009a). The MPA classification system consists of five key functional criteria that objectively describe MPAs:

- Conservation focus (i.e., sustainable production or natural and/or cultural heritage),
- Level of protection (i.e., no access, no impact, no-take, zoned with no-take area(s), zoned multiple use, or uniform multiple use),
- Permanence of protection,
- Constancy of protection,
- Ecological scale of protection (NMPAC, 2009a).

The first two of these criteria, conservation and protection, are the keystones of the classification system. These five criteria influence the effect MPAs have on the local ecosystem and on human users.

In April of 2009, the NMPAC, in collaboration with federal, state, and territory agencies, tribes, advisory committees, non-governmental organizations/associations, industry, and the public, announced the establishment of the National MPA System with its initial listing of over 200 MPAs. The list of National System MPAs contains all the mutually accepted MPAs that were nominated during the initial listing. Eligible MPAs can become part of the national system by applying to the NMPAC through their managing agency.

Federal agencies that function in the marine or aquatic environment have a responsibility under EO 13158. Section 5 of EO 13158 stipulates, "…each Federal agency whose actions affect the natural or cultural resources that are protected by MPAs shall identify such actions. To the extent permitted by law and to the maximum extent practicable, each federal agency, in taking such actions, shall avoid harm to the natural and cultural resources that are protected by an MPA."

Of the more than 200 National System MPAs, only seven of those listed in the National System MPAs are in potential SURTASS LFA sonar operating areas, largely because a part or their entire seaward boundary is located beyond 22 km (12 nmi) from the coastline. These MPAs include:

- Stellwagen Bank NMS
- Olympic Coast NMS
- Gulf of the Farallones NMS
- Monterey Bay NMS
- Cordell Bank NMS
- Hawaiian Islands Humpback Whale NMS (only Penguin Bank area)
- Papahānaumokuākea Marine NM (NOAA, 2009).

9.3.2.2 International Marine Protected Areas

Although there are several efforts to document international MPAs, no network or system of international MPAs currently exists. International MPAs encompass a very wide variety habitat types and types of MPAs as well as a good degree of variability in the levels of protection and legal mandates associated with each MPA. It is, thus, even more difficult to compile an international list of MPAs than it is in the U.S. MPAs have been designated by nearly every coastal country of the world, and by current estimates, more than 5,000 MPAs exist globally (Agardy et al., 2003; WDPA, 2009). International waters (i.e., the high seas) are contained within the boundaries of some MPAs such as the Pelagos Sanctuary for the Conservation of Marine Mammals in the Mediterranean (WDPA, 2009). A number of international MPAs have been established for the sole purpose of protecting cetaceans.

Although most international MPAs lie along the coast of the designating country, some international MPAs encompass large extents of ocean area and encompass international as well as territorial waters. Many of the large oceanic MPAs are also listed as World Heritage Sites (UNESCO, 2009).

Excluding the Arctic and Antarctic regions of the world's oceans, approximately 10 internationally-designated MPAs exist in waters in which SURTASS LFA sonar may potentially operate. The largest of these MPAs, Phoenix Islands Protected Area, established by the Republic of Kiribati in the southern Pacific Ocean, encompasses 415,000 km^2 of ocean area (WDPA, 2009).

9.3.2.3 Effects of Sonar on Marine Protected Areas

Many MPAs around the world that were established specifically to protect marine mammals have been considered during the OBIA selection process. Several of the marine mammal MPAs are amongst the 21 global OBIAs where SURTASS LFA sonar use will be restricted to keeping the >180 dB re 1 µPa (rms) sound field out of the areas during biologically important seasons. Areas such as Penguin Bank, of the Hawaiian Islands Humpback Whale National Marine Sanctuary and an area in the northern Ligurian Sea, part of the Pelagos Whale Sanctuary, for example, have been designated as OBIAs so that these critical areas for marine mammals are restricted from SURTASS LFA sonar use.

10 IMPACTS TO MARINE MAMMALS FROM HABITAT LOSS OR MODIFICATION

Requirement 10: *Anticipated impact of the loss or modification of the habitat on the marine mammal populations involved.*

Use of up to four SURTASS LFA sonar systems in ocean areas beyond 22 km (12 nmi) from shore, outside of potential OBIAs, and in non-polar waters will not impact the habitat of marine mammals nor result in loss or modification of marine habitat. Although SURTASS LFA sonar will not harm the marine habitat, certain mitigation measures are undertaken to further guard the resources of specific types of protected habitats such as marine mammals in OBIAs and MPAs.

11 MEANS OF EFFECTING LEAST PRACTICABLE ADVERSE IMPACTS—MITIGATION MEASURES

Requirement 11: *Availability and feasibility (economic and technological) of equipment, methods, and manner of conducting such activity or other means of effecting the least practicable adverse impact upon the affected species or stocks, their habitat, and on their availability for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance.*

Mitigation, as defined by the Council on Environmental Quality (CEQ), includes measures to minimize impacts by limiting the degree or magnitude of a proposed action and its implementation. The objective of the mitigation and monitoring measures presented for use when SURTASS LFA sonar is transmitting are designed to effect the least practicable adverse impact on marine mammal species or stocks and to avoid risk of injury to marine mammals, sea turtles, and human divers. These objectives are met by:

- Ensuring that coastal waters within 22 km (12 nmi) of shore are not exposed to SURTASS LFA sonar signal RLs >180 dB re 1 µPa (rms) (sound pressure level [SPL]);
- Ensuring that no OBIAs are exposed to SURTASS LFA sonar signal RLs >180 dB re 1 µPa (rms) during biologically important seasons; and
- Minimizing exposure of marine mammals to SURTASS LFA sonar signal RLs below 180 dB re 1 µPa (rms) by monitoring for their presence and suspending transmissions when one of these animals enters this mitigation zone.

Strict adherence to these measures will minimize impacts on marine mammal stocks and species as well as on sea turtle stocks and recreational or commercial divers.

11.1 GEOGRAPHIC RESTRICTIONS

Specifically, the above listed mitigation objectives are achieved by adherence to the following geographic restrictions that apply to the employment of SURTASS LFA sonar:

- SURTASS LFA sonar-generated sound field would be below RLs of 180 dB re 1 µPa (rms) (SPL) within 22 km (12 nmi) of any coastline;
- SURTASS LFA sonar-generated sound field would be below RLs of 180 dB re 1 µPa (rms) in the boundaries of the 21 potential LFA MM OBIAs;
- SURTASS LFA sonar operators would estimate LFA sound field RLs (SPL) prior to and during operations to provide the information necessary to modify operations, including the delay or suspension of transmissions, not to exceed received levels of 180-dB re 1 µPa (rms) sound field criteria cited above.

11.1.1 INTERIM OPERATIONAL RESTRICTIONS

In the SURTASS LFA 2002 to 2007 Final Rule under the MMPA (NOAA, 2002b), NMFS added an interim operational restriction to preclude the potential for injury to marine mammals from resonance effects by establishing a 1-km (0.54-nmi) buffer shutdown zone outside of the LFA mitigation zone. In the current five-year Rule (2007 to 2012), NMFS once more required that the 1-km (0.54 nmi) buffer zone interim operational restriction be adhered to. This restriction has proven to be practical under current operations; but the analysis, provided in Subchapter 2.5.1 of the SURTASS LFA Sonar FSEIS (DoN, 2007a) demonstrates that it did not appreciably minimize adverse impacts below 180-dB re 1 µPa (rms) RL. Thus, the removal of this interim operational restriction would not generate a change of any significance in the percentage of animals potentially affected. However, the Navy will adhere to the 1-km buffer zone if implemented by NMFS in the new Rule. Subchapter 2.5.1 of the FSEIS is incorporated herein by reference.

11.1.2 OFFSHORE BIOLOGICALLY IMPORTANT AREAS (OBIAS)

Areas of the world's oceans that are biologically important to marine mammals during specific times of year will have restrictions placed on the use of SURTASS LFA sonar transmissions. Sonar transmissions in these areas would be conducted so that the generated sound field is below RLs of 180 dB re 1 µPa (rms) at the boundary of an OBIA. OBIAs are part of a comprehensive suite of mitigation measures used in previous authorizations to minimize impacts and adverse effects to marine mammals. The SURTASS LFA sonar sound field would be estimated in accordance with the guidelines listed below.

11.1.3 SOUND FIELD MODELING

SURTASS LFA sonar operators estimate LFA sound field received levels (SPL) prior to and during operations to provide the information necessary to modify operations, including the delay or suspension of transmissions, so that the sound field criteria cited in this chapter are not exceeded. Sound field limits are estimated using near-real-time environmental data and underwater acoustic performance prediction models. These models are an integral part of the SURTASS LFA sonar processing system. The acoustic models help determine the sound field by predicting the SPLs, or RLs, at various distances from the SURTASS LFA sonar source location. Acoustic model updates are nominally made every 12 hr, or more frequently when meteorological or oceanographic conditions change.

If the sound field criteria were exceeded, the sonar operator would notify the Officer in Charge (OIC), who would order the delay or suspension of transmissions. If it were predicted that the SPLs would exceed the criteria within the next 12 hr period, the OIC would also be notified in order to take the necessary action to ensure that the sound field criteria would not be exceeded.

11.1.4 PREVIOUSLY CONSIDERED MITIGATION MEASURES

The following mitigation measures were considered in the previous SURTASS LFA sonar NEPA documents but not carried forward. The FSEIS (DoN, 2007) evaluated the use of small boats and aircraft for pre-operational surveys but concluded that these surveys were not feasible because they were not practicable, not effective, might increase the harassment of marine mammals, and were not safe to the human performers. Therefore, under the revisions to the MMPA by the NDAA FY04, pre-operational surveys were not considered as a viable mitigation option. Also considered and analyzed in FSEIS (DoN, 2007) was an increase in the coastal standoff distance to 46 km (25 nmi); this analysis showed that, overall, there is a greater risk of potential impacts to marine animals with the increase of the coastal standoff distance from 22 km (12 nmi) to 46 km (25 nmi). This is due to an increase in the affected area with less of the ensonified annuluses overlapping land for the 46 km (25 nmi) standoff distance than for the 22 km (12 nmi) standoff distance.

11.2 MONITORING TO PREVENT INJURY TO MARINE ANIMALS

The following monitoring to prevent injury to marine animals is required when employing SURTASS LFA sonar:

- **Visual monitoring** for marine mammals and sea turtles from the vessel during daylight hours by personnel trained to detect and identify marine mammals and sea turtles;
- **Passive acoustic monitoring** using the passive (low frequency) SURTASS array to listen for sounds generated by marine mammals as an indicator of their presence; and
- **Active acoustic monitoring** using the High Frequency Marine Mammal Monitoring (HF/M3) sonar, which is a Navy-developed, enhanced HF commercial sonar, to detect, locate, and track marine mammals and, to some extent, sea turtles, that may pass close enough to the SURTASS LFA sonar's transmit array to enter the LFA mitigation zone.

All sightings are recorded in the log and provided as part of the Long Term Monitoring (LTM) Program to monitor for potential long-term environmental effects.

11.2.1 VISUAL MONITORING

Visual monitoring includes daytime observations for marine mammals and sea turtles from the vessel. Daytime is defined as 30 minutes before sunrise until 30 minutes after sunset. Visual monitoring begins 30 minutes before sunrise or 30 minutes before the SURTASS LFA sonar is deployed. Monitoring continues until 30 minutes after sunset or until the SURTASS LFA sonar is recovered. Observations are made by personnel trained in detecting and identifying marine mammals and sea turtles. Marine mammal biologists qualified in conducting at-sea marine mammal visual monitoring from surface vessels train and qualify designated ship personnel to conduct at-sea visual monitoring. The objective of these observations is to maintain a track of marine mammals (and/or sea turtles) observed and to ensure that none approach the source close enough to enter the LFA mitigation zone.

These trained personnel maintain a topside watch and marine mammal/sea turtle observation log during operations that employ SURTASS LFA sonar in the active mode. The numbers and identification of marine mammals/sea turtles sighted, as well as any unusual behavior, is entered into the log. A designated ship's officer monitors the conduct of the visual watches and periodically reviews the log entries. There are two potential visual monitoring scenarios.

First, if a potentially affected marine mammal is sighted outside of the LFA mitigation zone, the observer notifies the OIC. The OIC then notifies the HF/M3 sonar operator to determine the range and projected track of the animal. If it is determined that the animal will pass within the LFA mitigation zone, the OIC orders the delay or suspension of SURTASS LFA sonar transmissions when the animal enters the LFA mitigation zone. If the animal is visually observed within 2 km (1.1 nmi) and 45 degrees either side of the bow, the OIC orders the immediate delay or suspension of SURTASS LFA sonar transmissions. The observer continues visual monitoring/recording until the animal is no longer seen. Second, if the potentially affected animal is sighted anywhere within the LFA mitigation zone, the observer notifies the OIC who orders the immediate delay or suspension of SURTASS LFA sonar transmissions. All sightings are recorded in the log and provided as part of the LTM Program.

11.2.2 PASSIVE ACOUSTIC MONITORING

Passive acoustic monitoring is conducted when SURTASS is deployed, using the SURTASS towed horizontal line array (HLA) to listen for vocalizing marine mammals as an indicator of their presence. If the sound is estimated to be from a marine mammal that may be potentially affected by SURTASS LFA sonar, the technician notifies the OIC who alerts the HF/M3 sonar operator and visual observers. If prior to or during transmissions, the OIC then orders the delay or suspension of SURTASS LFA sonar transmissions when the animal enters the LFA mitigation zone. All contacts are recorded in the log and provided as part of the LTM Program.

11.2.3 ACTIVE ACOUSTIC MONITORING

HF active acoustic monitoring uses the HF/M3 sonar to detect, locate, and track marine mammals (and possibly sea turtles) that could pass close enough to the SURTASS LFA sonar array to enter the LFA mitigation zone. HF/M3 acoustic monitoring begins 30 minutes before the first SURTASS LFA sonar transmission of a given mission is scheduled to commence and continues until transmissions are terminated. Prior to full-power operations, the HF/M3 sonar power level is ramped up over a period of 5 minutes from the source level of 180 dB re 1 µPa @ 1 m (SPL) in 10-dB increments until full power (if required) is attained to ensure that there are no inadvertent exposures of local animals to received levels $\geq$180 dB re 1 µPa (rms) from the HF/M3 sonar. There are two potential scenarios for mitigation via active acoustic monitoring.

If a contact is detected outside the LFA mitigation zone, the HF/M3 sonar operator determines the range and projected track of the animal. If it is determined that the animal will pass within the LFA mitigation zone, the sonar operator notifies the OIC. The OIC then orders the delay or suspension of transmissions when the animal is predicted to enter the LFA mitigation zone. Second, if a contact is detected by the

HF/M3 sonar within the LFA mitigation zone, the observer notifies the OIC who orders the immediate delay or suspension of transmissions. All contacts are recorded in the log and provided as part of the LTM Program.

11.2.4 RESUMPTION OF SURTASS LFA SONAR TRANSMISSIONS

SURTASS LFA sonar transmissions can commence/resume 15 minutes after there is no further detection by the HF/M3 sonar and there is no further visual observation of the animal within the LFA mitigation zone.

11.3 SUMMARY OF MITIGATION MEASURES FOR SURTASS LFA SONAR USE

There are geographic restrictions that apply to the operation of SURTASS LFA sonar as well as three types of monitoring measures that comprehensively are designed to mitigate adverse impacts to marine mammals when the sonar is in use (Table 30).

Table 30. Summary of mitigation measures for operation of SURTASS LFA sonar.

MITIGATION MEASURE	CRITERIA	ACTIONS
Geographic Restrictions		
22 km (12 nmi) from coastline	Sound field below 180 dB RL, based on SPL modeling	Delay/suspend SURTASS LFA sonar operations if sound field criterion is exceeded
Offshore biologically important areas (OBIA) during biologically important seasons	Sound field below 180 dB RL, based on SPL modeling	Delay/suspend SURTASS LFA sonar operations if sound field criterion is exceeded
Monitoring to Prevent Injury to Marine Mammals and Sea Turtles		
Visual Monitoring	Potentially affected species near the vessel but outside of the LFA mitigation zone	Notify OIC
	Potentially affected species sighted within 2 km (1.1 nmi) and 45 degrees either side of the bow or inside of the LFA mitigation zone	Delay/suspend SURTASS LFA sonar operations
Passive Acoustic Monitoring	Potentially affected species detected	Notify OIC
Active Acoustic Monitoring	Contact detected and determined to have a track that would pass within the LFA mitigation zone	Notify OIC
	Potentially affected species detected inside of the LFA mitigation zone	Delay/suspend SURTASS LFA sonar operations

12 MINIMIZATION OF ADVERSE EFFECTS ON SUBSISTENCE USES

<u>Requirement 12</u>: *Where the proposed activity would take place in or near a traditional Arctic subsistence hunting area and/or may affect the availability of a species or stock of marine mammals for Arctic subsistence uses, the applicant must submit either a "plan of cooperation" or information that identifies what measures have been taken and/or will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses.*

Although SURTASS LFA sonar may be operated in the Gulf of Alaska where subsistence hunting of harbor seals and Steller sea lions occurs, the sonar would not be operated in the vicinity of any of coastal and inshore locations where hunting of these species occurs due to the geographic restrictions on the sonar use (coastal standoff range and OBIAs). Additionally, a suite of mitigation measures associated with the employment of SURTASS LFA sonar, including passive, active, and visual monitoring, are implemented to prevent injury or harm to marine mammals. Alaskan Native groups that subsistence hunt the two pinniped species in the Gulf of Alaska are being sent a copy (via the Alaska Command [ALCOM] Native Liaison) of the Draft SEIS/SOEIS that the DoN prepared for the employment of SURTASS LFA sonar. They will be asked to provide comments on the document regarding the potential for significant impact on any of their Tribal rights or resources from the proposed action. The employment of SURTASS LFA sonar will not lead to any adverse effects on subsistence-hunted marine mammals nor will it reduce the availability of marine mammal stocks or species for subsistence uses. For this reason, a cooperation plan is not applicable to this activity.

13 MONITORING AND REPORTING

<u>*Requirement 13*</u>: *The suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities and suggested means of minimizing burdens of coordinating such reporting requirements with other schemes already applicable to persons conducting such activity. Monitoring plans should include a description of the survey techniques that would be used to determine the movement and activity of marine mammals near the activity site(s) including migration and other habitat uses, such as feeding. Guidelines for developing site-specific monitoring plan may be obtained by writing to the Director, Office of Protected Resources.*

13.1 MONITORING AND REPORTING

During the routine operations of the SURTASS LFA sonar system, the Navy records technical and environmental data from visual and acoustic monitoring, ocean environmental measurements (SSP, ambient noise, etc.), and technical and operational inputs. This information becomes part of the Long Term Monitoring Program. Further, the Navy submits quarterly, classified mission reports to the Director, Office of Protected Resources, NMFS no later than 30 days after the end of each quarter. Each quarterly, classified mission report includes all active-mode missions that have been completed during the quarter. Specifically, these reports will include dates/times of exercises, location of vessel, LOA province, location of the safety and buffer zones in relation to the LFA sonar array, marine mammal observations, and records of any delays or suspensions of operations. Marine mammal observations will include animal type and/or species, number of animals sighted, date and time of observations, type of detection (visual, passive acoustic, HF/M3 sonar), bearing and range from the vessel, abnormal behavior (if any), and remarks/narrative (as necessary). The report will include the Navy's assessment of whether any taking occurred within the SURTASS LFA sonar safety and buffer zone (if required) and estimates of the percentage of marine mammal stocks affected by SURTASS LFA sonar operations (both within and outside the safety and buffer zones), using predictive modeling based on operating locations, dates/times of operations, system characteristics, oceanographic environmental conditions, and animal demographics. Upon NMFS' request, the Navy may provide an unclassified version of the quarterly reports, as feasible and predicated upon budget availability.

The Navy will also submit an annual, unclassified report to the Director, Office of Protected Resources, NMFS. This report will provide NMFS with an unclassified summary of the year's quarterly reports and will include the Navy's assessment of whether any taking occurred within the SURTASS LFA sonar mitigation and buffer zones and estimates of the percentage of marine mammal stocks affected by SURTASS LFA sonar operations (both within and outside the safety and buffer zones), using predictive modeling based on operating locations, dates/times of operations, system characteristics, oceanographic environmental conditions, and animal demographics. The annual report will also include an analysis of the effectiveness of the mitigation measures with recommendations for improvements where applicable, an assessment of any long-term effects from SURTASS LFA sonar operations, and any discernible or estimated cumulative impacts from SURTASS LFA sonar operations.

13.2 LONG TERM MONITORING PROGRAM (LTM)

The principal objectives of the LTM Program for the SURTASS LFA sonar system are to:

1. Conduct Navy and independent scientific analyses of the effectiveness of proposed mitigation measures, make recommendations for improvements where applicable, and incorporate them as early as possible, with NMFS' concurrence.
2. Provide the necessary input data for LOA reports to NMFS on assessment of whether any taking of marine mammal(s) occurred within the LFA mitigation zone (180-dB sound field) during SURTASS LFA sonar operations. This would entail tabular information that includes: date/time; vessel name; LOA area; marine mammals affected (number and type); assessment basis (observed injury, behavioral response, or model calculation); LFA mitigation zone radius; bearing from vessel; whether operations were delayed, suspended or terminated; and narrative.
3. Study the potential effects of Navy SURTASS LFA sonar-generated underwater sound on long-term ecological processes relative to LF sound-sensitive marine mammals and sea turtles, focusing on the application of Navy technology for the detection, classification, localization, and tracking of these animals, using data from the IUSS seafloor arrays, as feasible, and the SURTASS towed passive horizontal line array, coupled with results from annual acoustic analyses conducted for LOA applications.
4. Collaborate, as feasible, with pertinent Navy, academic, and industry laboratories and research organizations on field research efforts to help fill scientific data gaps.

13.2.1 LTM Program Elements

The LTM Program includes the elements described below. The primary product from the LTM Program is annual reports submitted to NMFS (public record) that include the following:

- Summary of the unclassified SURTASS LFA sonar operations during the past year;
- Summary of unclassified plans for the following year;
- Assessment of the efficacy of mitigation measures used during the past year, as well as the value-added from the various LTM elements, with recommendations for improvements (and NMFS concurrence where applicable);
- Synopsis of LOA reports to NMFS on estimates of percentages of marine mammal stocks affected by SURTASS LFA sonar operations; and
- Assessment of any long-term ecological processes that may be exhibiting effects from SURTASS LFA sonar operations, and reports or scientific papers on discernible or estimated cumulative impacts from such operations.

13.2.1.1 Environmental Data Monitoring

The Navy will deploy expendable bathythermographs (XBT); nominally once every 12 hours, to collect environmental data (i.e., temperature gradients and depth) during SURTASS LFA sonar operations and, as feasible, during the vessel's transits to and from the mission area.

On a pre-assigned schedule, the Navy Military Detachment (MILDET) onboard each SURTASS LFA sonar vessel will forward these data to the Naval Oceanographic Office at Bay St. Louis, MS for processing and inclusion into the Navy's environmental databases, including the generalized digital environmental model (GDEM), the oceanographic and atmospheric master library (OAML), and the modular ocean data assimilation system (MODAS). GDEM products are available to the public directly, while MODAS records are available to the public through the Navy's Commander Naval Meteorology and Oceanography Command. OAML products are available to the public through the Navy's Commander Naval Meteorology and Oceanography Command.

Because the Navy conducts SURTASS LFA sonar operations in the world's oceans and littoral areas, incorporation of these monitoring data sets will provide the Navy and the general public with more robust and up-to-date global temperature and salinity profiles in data-poor and/or shallow areas. Inclusion of these new datasets will lead to increased gridded resolution within the Navy's current climatology data bases (i.e., GDEM, MODAS, and OAML).

The determination of the movement and activity of marine mammals, and information on the migration and other marine habitat uses of marine mammals rely on accurate and reliable data from the GDEM, MODAS and OAML data bases Thus, the SURTASS LFA sonar program's monitoring datasets will lead to increased knowledge of habitat use, improve the public's predictive capabilities for determining marine mammal occurrence, and refine models of acoustic effects on the environment. Further, these data are utilized in the planning of future SURTASS LFA and other Navy ASW exercises, for input to marine mammal impact models.

13.2.1.2 Ambient Noise Data Monitoring

Several efforts (federal and academic) are underway to develop a comprehensive ocean noise budget (i.e., an accounting of the relative contributions of various underwater sources to the ocean noise field) for the world's oceans that include both anthropogenic and natural sources of noise. Ocean noise distributions and noise budgets are used in marine mammal masking studies, habitat characterization, and marine animal impact analyses.

The Navy will collect ambient noise data when the SURTASS passive towed horizontal line array is deployed. The Navy is exploring the feasibility of declassifying and archiving the ambient noise data for incorporation into appropriate ocean noise budget efforts. Thus, the SURTASS LFA sonar vessels could serve as *ad hoc* ships of opportunity for monitoring data that could provide validation of marine mammal-relevant global ocean noise budgets by supplying up-to-date measurements of the underwater noise field in data-poor and/or littoral areas not previously surveyed.

13.2.2 IUSS Marine Mammal Monitoring Program

The IUSS Marine Mammal Monitoring (M3) Program uses the Navy's permanent seafloor sensor arrays in designated ocean areas to passively monitor the movements of some large cetaceans, including their migration and feeding patterns, by tracking them through their vocalizations. Analysts can not only count numbers of whales, but in some cases also note the interaction and influence of underwater noise sources on the animals. Some whales are vocal enough to allow long-term tracking; e.g., in 2010 a blue whale was tracked for 67 days, with the animal travelling over 1,800 nmi. Recently, upgraded acoustic signal processing systems have allowed for detection of sperm whale clicks—longest holding to date of one sperm whale is 12 hours, which included 14 dives. At present, most of the data resulting from the M3 Program are classified. However, the Navy is currently working toward the de-classification of specified data, such that it can be made available to the public.

13.2.3 Incident Monitoring

This LTM program element comprises two parts: 1) recreational or commercial diver incident monitoring, and 2) marine mammal stranding incident monitoring. The Navy monitors the principal clearinghouses for information on diver-related incidents, namely the National Association of Underwater Instructors (NAUI), Professional Association of Diving Instructors (PADI) and Divers Alert Network (DAN). The Navy also monitors the principal marine mammal stranding networks and other media to correlate analysis of any whale strandings that could potentially be associated with SURTASS LFA sonar operations.

13.3 MONITORING STUDY

<u>Passive acoustic monitoring with fleet exercises</u>. For fleet exercises that SURTASS LFA sonar is involved in, the Navy is exploring the feasibility of coordinating with other fleet assets and/or range monitoring programs to include the use of SURTASS towed horizontal line arrays to augment the collection of marine mammal vocalizations before, during, and after designated exercises. The goal would be to determine the extent, if any, of changes in marine mammal vocalizations that could have been caused by SURTASS LFA sonar operations during the exercise. This applies directly to increased knowledge of marine mammal species. If the collection of such calibrated and validated data can occur, this could be useful information in NMFS' environmental compliance processes for underwater LF sonar systems.

This effort would require detailed pre-planning and a comprehensive data collection and analysis plan, which will necessarily be subject to the fleet operations plan for the exercise itself. Other factors that would need to be addressed include the following:

- Scheduling of assets: availability of the SURTASS LFA sonar vessel prior to commencement of the fleet exercise, and the time limit on that availability for pre-exercise marine mammal vocalization data collection.
- Scheduling of assets: availability of the SURTASS LFA sonar vessel after the end of the fleet exercise, and the time limit on that availability for post-exercise marine mammal vocalization data collection.
- Budgetary constraints: additional Navy budget allocations required for extra time at sea for the SURTASS LFA sonar vessel pre- and post-exercise.
- Potential for qualified, professional marine mammal biologists to ride the SURTASS LFA sonar vessel during the data collection efforts. There is typically little available space on the T-AGOS vessels for any additional riders, and any riders would need to have appropriate security clearances.
- Security measures: protocols would need to be developed to ensure that the marine mammal vocalization data collected onboard the SURTASS LFA sonar vessel during the fleet exercise can be scrubbed of any potentially classified information, such that the marine mammal data can be unclassified for processing and analysis by other scientists.
- De-conflicting any potential behavioral responses of marine mammals in the fleet exercise area from other underwater sound sources (e.g., mid-frequency active sonars) with potential behavioral responses from SURTASS LFA sonar transmissions.
- Accounting for other variables that may cause a change in marine mammals' vocalization output; this would be a task for a scientific team made up of marine biologists, LFA operators, and meteorological/oceanographic experts.

13.4 ADAPTIVE MANAGEMENT

The Navy's understanding of the potential effects of SURTASS LFA sonar on marine mammals is continually evolving, as the science in this field addresses new hypotheses as to the reasoning behind the effects of anthropogenic underwater sound on marine species. These circumstances make the inclusion of adaptive management appealing within the context of five-year NMFS regulations for permitting the incidental harassment of marine mammals. The Navy proposes to include an adaptive management component within the framework of the scientific underpinning of its Supplemental EIS/Supplemental OEIS that supports this application for letters of authorization and rulemaking. This allows the Navy, in concert with NMFS, to consider, on a case-by-case basis, new/revised peer-reviewed and published scientific data and information from different qualified and recognized sources within academia, industry, and government/non-government organizations, in order to determine (with input regarding practicability) whether consideration should be given to the modification of current SURTASS LFA sonar mitigation and monitoring measures (including additions or deletions); if new scientific data indicate that such modifications would be appropriate. It also allows for updates to marine mammal stock estimates which, in turn, provides for the use of the best available scientific data for predictive models, including AIM©.

14 RESEARCH

> <u>*Requirement 14*</u>: *Suggested means of learning of, encouraging, and coordinating research opportunities, plans, and activities relating to reducing such incidental taking and evaluating its effects.*

The Navy sponsors significant research and monitoring projects for marine living resources to study the potential effects of its activities on marine mammals. These funding levels have increased in recent years to $31M in FY 2009 and $32M in FY 2010 for marine mammal research and monitoring activities at universities, research institutions, federal laboratories, and private companies. Navy-funded research has produced, and is producing, many peer-reviewed articles in professional journals. Publication in open professional literature thorough peer review is the benchmark for the quality of the research. This ongoing marine mammal research includes hearing and hearing sensitivity, auditory effects, dive and behavioral response models, noise impacts, beaked whale global distribution, modeling of beaked whale hearing and response, tagging of free-ranging marine animals at-sea, and radar-based detection of marine mammals from ships. The Navy sponsors 70 percent of all U.S. research on the effects of human-generated underwater sound on marine mammals and 50 percent of such research conducted worldwide.

The Marine Life Sciences Division of the Office of Naval Research currently oversees six programs that examine the marine environment and are devotred to studying the effects of underwater sound and/or the implementation of technological tools that will assist the Navy in studying and tracking marine mammals. The six programs are:

- Environmental consequences of underwater sound.
- Non-auditory biological effects of sound on marine mammals.
- Effects of sound on the marine environment.
- Sensors and models for marine environment monitoring.
- Effects of sound on hearing of marine animals.
- Passive acoustic detection, classification, and tracking of marine mammals.

Research cruises by NMFS and academic institutions have received funds from the Navy. For example, in April 2009, the Commander U.S. Pacific Fleet contributed approximately $250,000 in support of a NMFS marine mammal density survey of the Gulf of Alaska's offshore waters. The objective of this survey was to increase the information on marine mammal occurrence, density and distribution within the Gulf of Alaska. This was a vessel-based line-transect survey conducted from onboard the NOAA ship *Oscar Dyson*. In addition, the Chief of Naval Operations Environmental Readiness Division and the Office of Naval Research have developed a coordinated science & technology and research and development program focuses on marine mammals and sound. Total investment in this program between 2004 and 2008 was $100 million. Fiscal year 2009 funding was $22 million.

The Navy continues to fund national and international research on the responses of deep diving odontocetes to sonar signals by independent scientists for whale behavioral response studies (BRSs) with Navy and NOAA funding support for the 2007, 2008, and 2009 BRSs. Findings from the Deep-Diving Odontocetes BRSs will be published in peer-reviewed literature.

BRS-07 took place in the Tongue of the Ocean (TOTO) and at the adjacent Atlantic Undersea Test and Evaluation Center (AUTEC) on Andros Island, Bahamas during August and September 2007. BRS-07 demonstrated that the feasibility of the approach and refined protocols. Direct visual observations were made when whales were at the surface, and passive acoustic measurements were recorded during foraging dives. Data was also collected from ten suction cup tags (six on Blainville's beaked whales and four on short-finned pilot whales. A total of 109 hours of data was collected from these tags. A Cruise Report on BRS-07 was prepared (Boyd, 2008a).

BRS-08 was conducted in the TOTO adjacent to AUTEC in August and -September 2008. The primary objectives and accomplishments were to: 1) Increase sample size of MF sonar signal playbacks and controls from that achieved in BRS-07 (the sample size was increased, but not as much as hoped); 2) Measure received levels of sonar sound that produce a behavioral response during playbacks (done); 3) Investigate variation in responses in relation to context and species (done—four species investigated); 4) Include at least one more killer whale playback to examine whether response of beaked whales might be explained by confusion between sonar signals and killer whale calls (not achieved primarily due to a greater than predicted number of inclement weather days); and 5) Compare responses to MF sonar signals versus more spread spectrum signal with similar overall bandwidth, duration and timing (achieved in some species). A Cruise Report on BRS-08 was prepared (Boyd, 2008b).

SOCAL-10 (Southern California) is the first phase of a multi-year research effort (2010 to 2015), notionally referred to as SOCAL-BRS, which is designed to contribute to emerging understanding of marine mammal behavior and changes in behavior as a function of sound exposure. It is in some ways an extension of previous Navy-sponsored BRS efforts in the Bahamas and Mediterranean Sea in 2007 through 2009, but is being constructively integrated with several related, ongoing, successful field efforts (e.g., population surveys of Navy range areas and satellite tagging before active sonar operations) already ongoing in southern California. The research is continuing as SOCAL-BRS (2010 to2015) to study diving, foraging, and vocal behavior in various marine mammals and their response to controlled sound exposures. The initial phase off southern California was successfully completed during the summer of 2010.

These research projects may not be specifically related to SURTASS LFA sonar operations; however, they are crucial to the overall knowledge base on marine mammals and the potential effects from underwater anthropogenic noise. The Navy is also sponsoring research to determine marine mammal abundances and densities for all Navy ranges and other operational areas.

The Navy notes that research and evaluation is being carried out on various monitoring and mitigation methods, including passive acoustic monitoring (PAM). The results from this research could be applicable to SURTASS LFA sonar passive acoustic monitoring.

The Navy has also sponsored several workshops to evaluate the current state of knowledge and potential for future acoustic monitoring of marine mammals. The workshops bring together underwater acoustic subject matter experts and marine biologists from the Navy and other research organizations to present data and information on current acoustic monitoring research efforts, and to evaluate the potential for incorporating similar technology and methods on Navy instrumented ranges. The Navy will consider the feasibility of conducting a workshop on mitigation and monitoring methodologies, and research results regarding SURTASS LFA sonar, predicated upon budgetary constraints.

14.1 RESEARCH AND PUBLICATIONS ON BEAKED WHALE HABITAT

The U.S. Navy/Office of Naval Research (ONR) has provided funding for research on beaked whales, which has resulted in the following published articles:

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- Zimmer, W.M.X., J. Harwood, P.L. Tyack, M.P. Johnson, and P.T. Madsen. 2008. Passive acoustic detection of deep-diving beaked whales. Journal of the Acoustical Society of America 124(5):2823-2832.
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